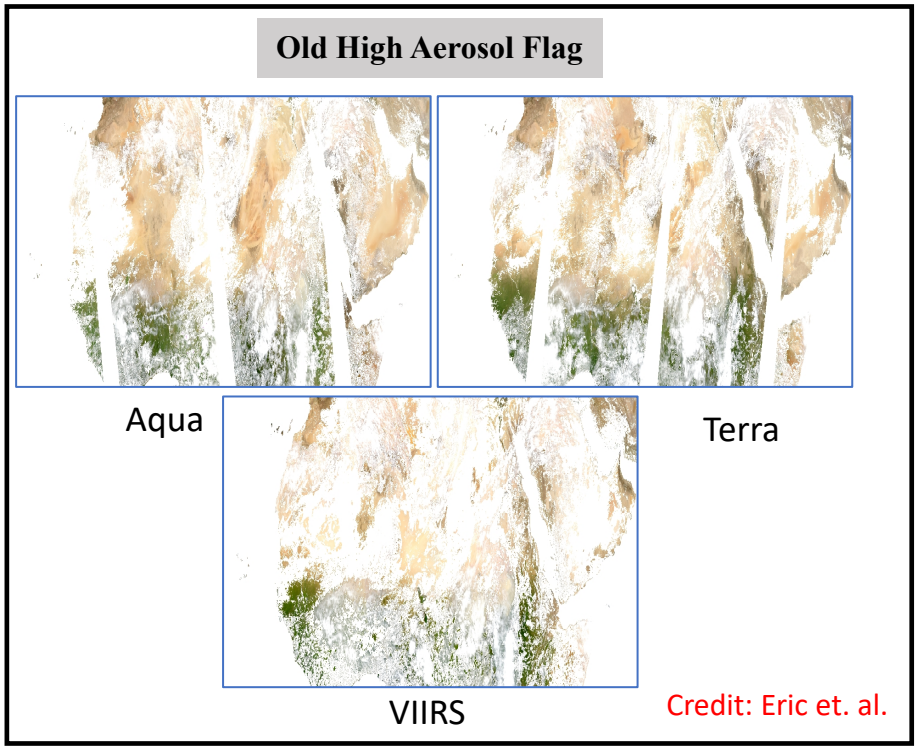
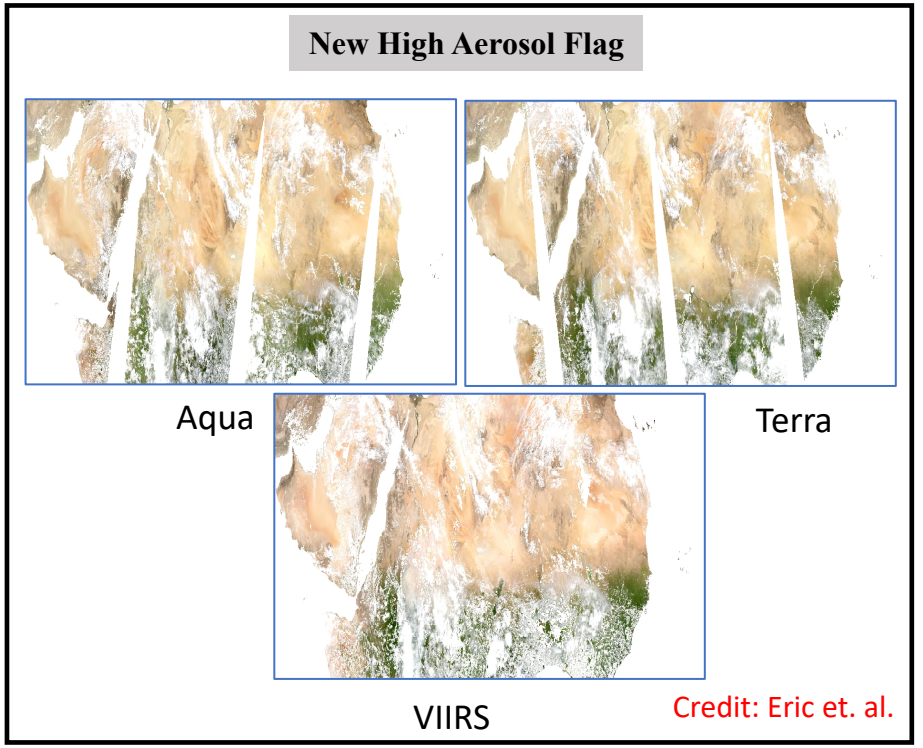
C61 Revision to MODIS Land Surface Reflectance (MxD09): Estimation of High Aerosols

A change in the approach to estimation of high aerosols in the MODIS and VIIRS Land Surface Reflectance (MxD09, VNP09) products, was prompted by overestimation of high-aerosol areas, especially over the brighter surfaces. This issue was found to be more extensive in VIIRS LSR than MODIS caused by use of an approximation on the path radiance. This approximation caused overestimation of high aerosol, mainly on bright surfaces and at higher view angles. Hence, the LSR science team decided to port a more robust scheme for estimating aerosol quantities, which has been in processing of Landsat and Sentinel 2, to MODIS and VIIRS LSR products. This revision made to both the MODIS and VIIRS LSR products does not change the retrieved reflectance but changes the quality flag "aerosol quantity" in the 1km surface reflectance state quality flag (QF7 Surface Reflectance – for VIIRS) dataset at pixel level. Most downstream LSR daily and n-day products like VI/BRDF-Albdeo, use the aerosol quantity flag to screen out high aerosol values. So any change in this quantification of the aerosol categories will have a definite impact on these downstream products.

Here, we highlight the impact of this change on L3 LSR and some of the key downstream products from MODIS C61 processing. The results presented here are largely based on a test of C61 L2 LSR PGEs: PGE11 Version 6.4.5 (Test) that used the new approach compared to Version 6.4.4 (Baseline) that used the older approach. All differences and statistics reported here are based on the comparison of this test with the baseline. We have also presented some key results from the corresponding S-NPP VIIRS test to stress on the consistency of the LSR products, across the different sensors.

Following figure shows true color RGB composite of L2 surface reflectance from Aqua and Terra MODIS and SNPP VIIRS when using the old and new approach to estimating the high aerosol. The white area are either no data (Terra and Aqua), ocean or high aerosol.





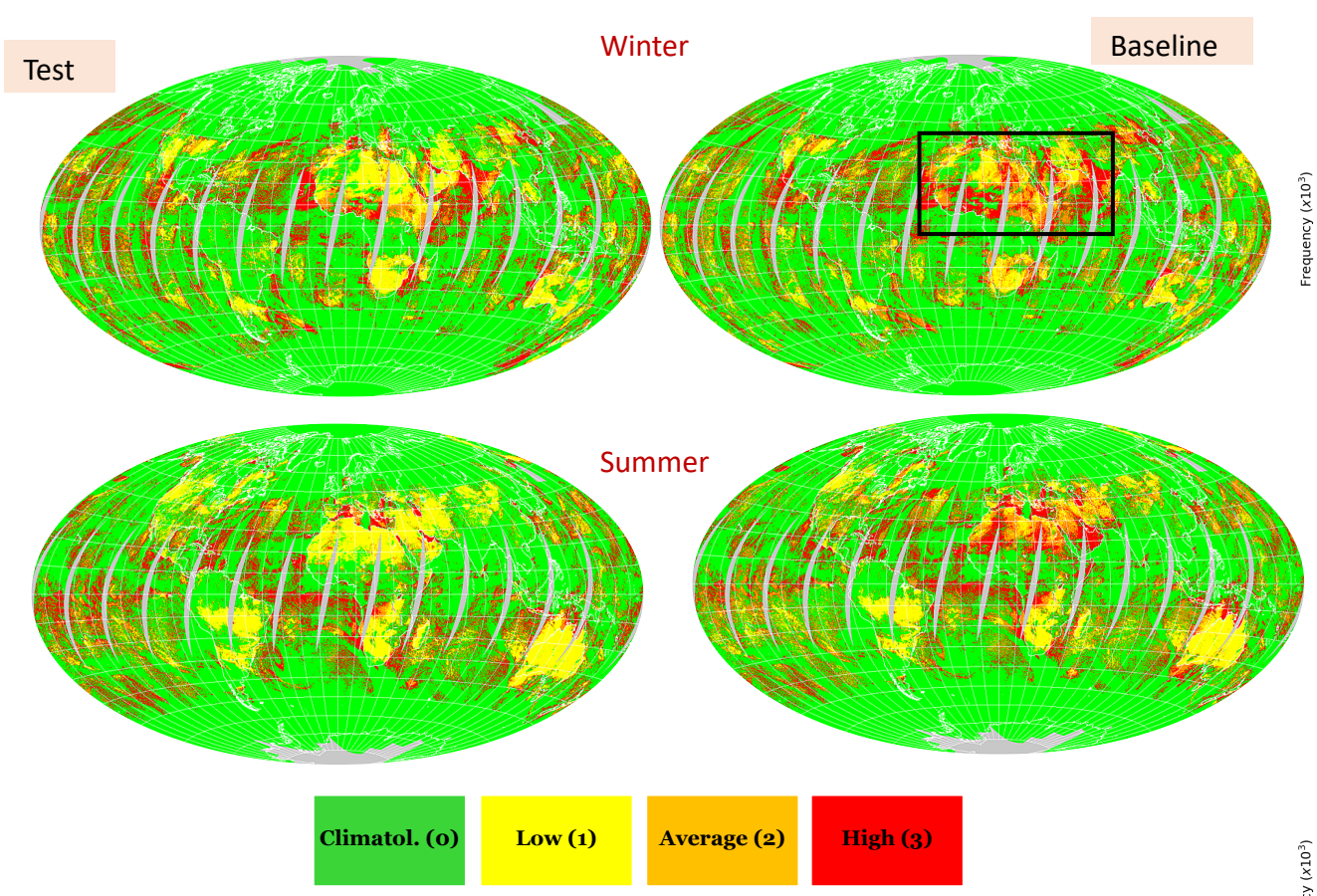
Test Definitions

MODIS	Test	Baseline
LAADS AS	1736	1737
Inputs	C61 L1B	C61 L1B
LSR PGE11	6.4.5 (new approach)	6.4.4 (old approach)

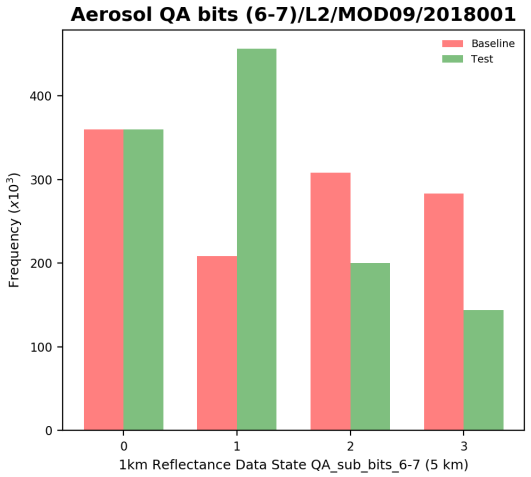
VIIRS	Test	Baseline
LAADS AS	3298	5000
Inputs	C2 NASA L1B	C1 IDPS SDR
LSR PGE511	2.0.3 (new approach)	1.0.13 (old approach)

L2 Land Surface Reflectance (MxD09)

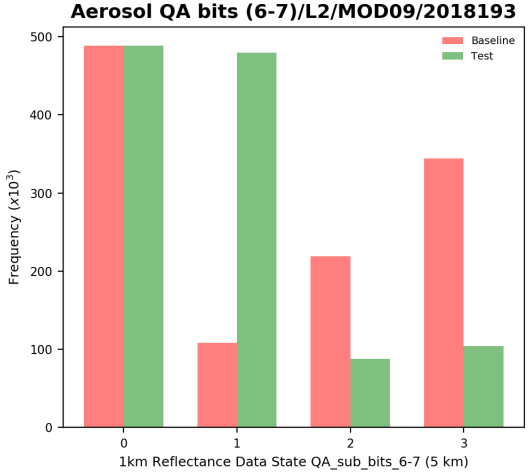
After this revision, though there isn't any change to the retrieved reflectance for any of the land bands and associated quality flags, there could be substantial changes in the distribution of high aerosols during both summer and winter seasons and mainly over the brighter surfaces and areas with extensive dust events. The figures below show the spatial distribution of the different aerosol classes, as computed from the 1km Reflectance Data State QA (Bits 6-7) in L2 MxD09 products. We see a change from predominantly high-aerosols to low-aerosol values, after the revision and over the brighter surfaces (black rectangle). The distribution of climatology aerosols remain the same as is expected.



Spatial distribution of the Aerosol quantities (State QA bits 6-7) between the test (left) and Baseline (right).



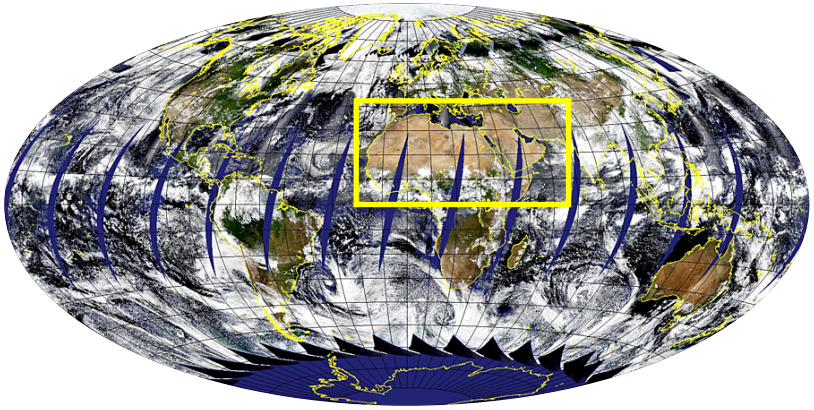
Distribution of the different Aerosol classes over the Sahara/ Arabian Peninsula Area (the Area within the black rectangle)

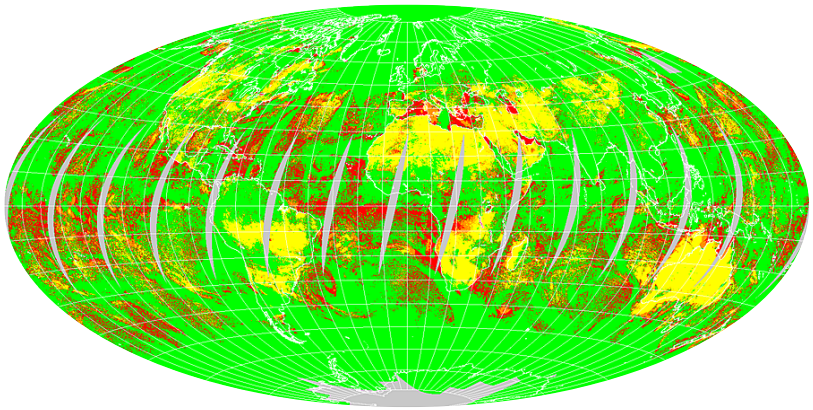


Test (AS1736)

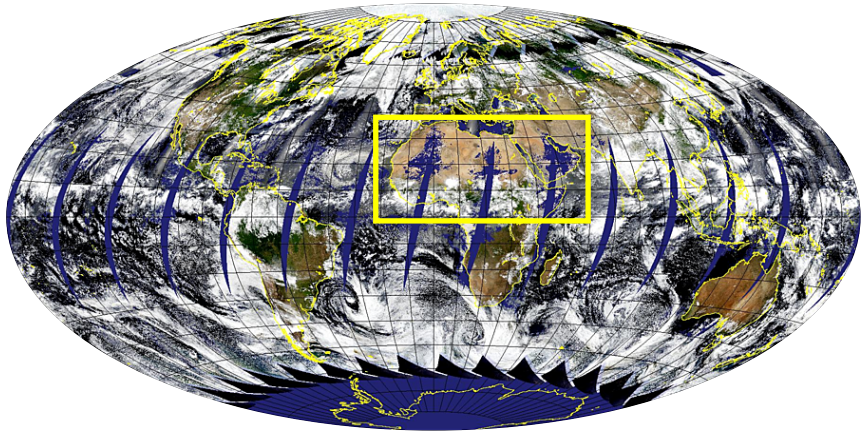
MOD09.2018193

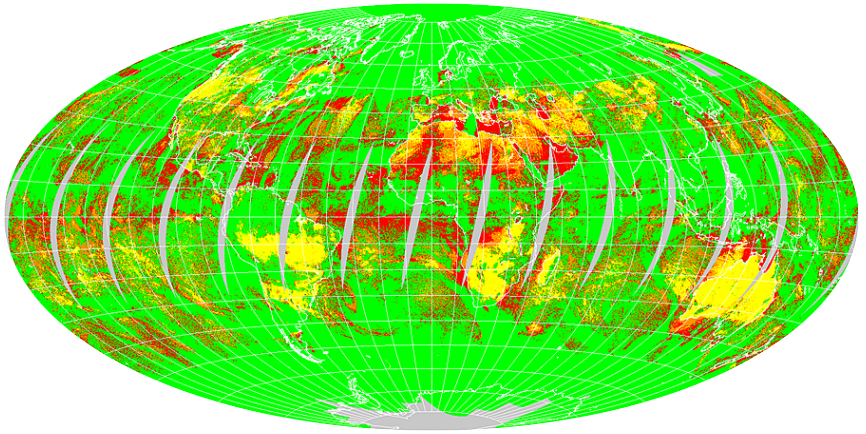
The global RGB (bands 1,4,3) browse of L2 MOD09, masked for all high – aerosols are shown in the left, while the distribution of the Aerosol quantities (bits 6-7, 1km State Flag) are shown in the right. The test shows more consistent and continuous retrieval, uninterrupted by false flagging of high aerosols, especially over the Sahara and Arabian Peninsula area (highlighted)





Baseline (AS 1737)



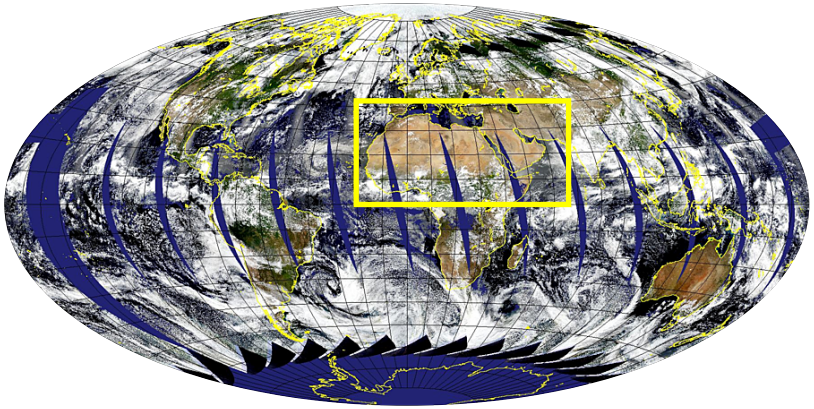


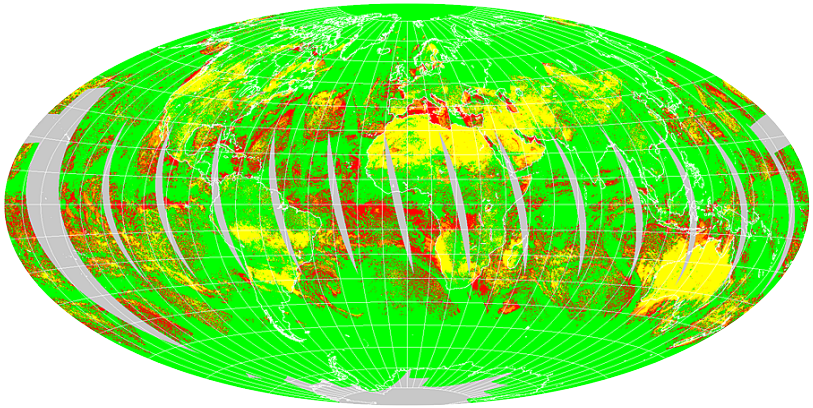
Climatol. (0) | Low (1) | Average (2) | High (3)

Test (AS 1736)

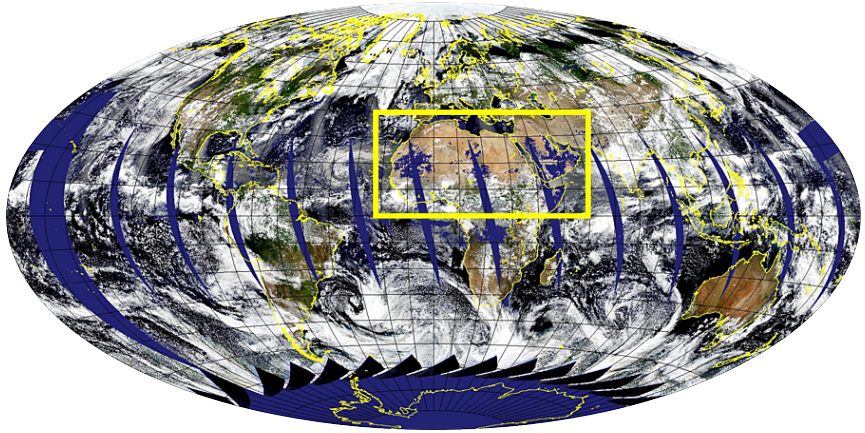
MYD09.2018193

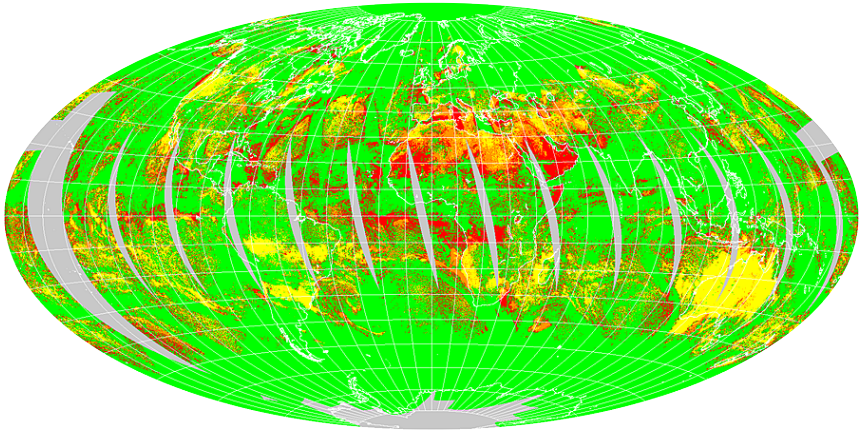
Like the previous slide, the global RGB (bands 1,4,3) browse of L2 MYD09, masked for all high – aerosols and the aerosol quanties have been shown in left and right respectively. Like Terra, the test shows more consistent and continuous retrieval, uninterrupted by false flagging of high aerosols, over the brighter surfaces





Baseline (AS 1737)

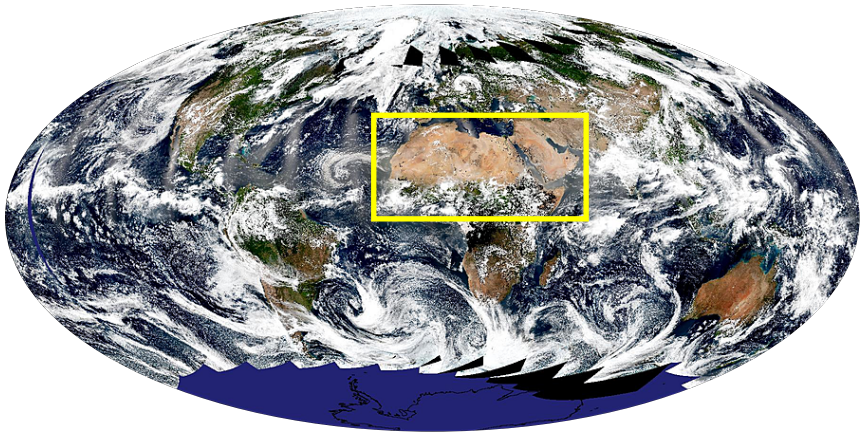


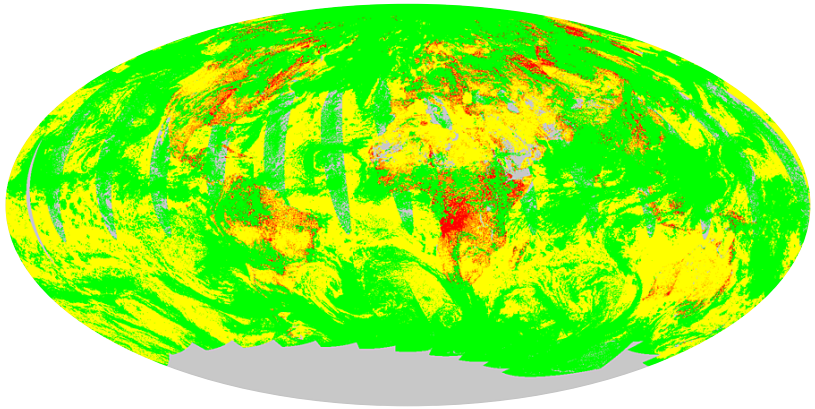


Test (AS 3298)

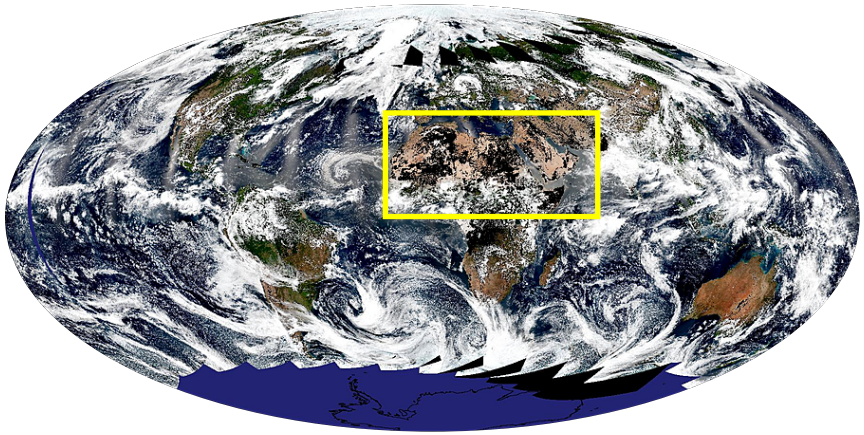
VNP09.2018193

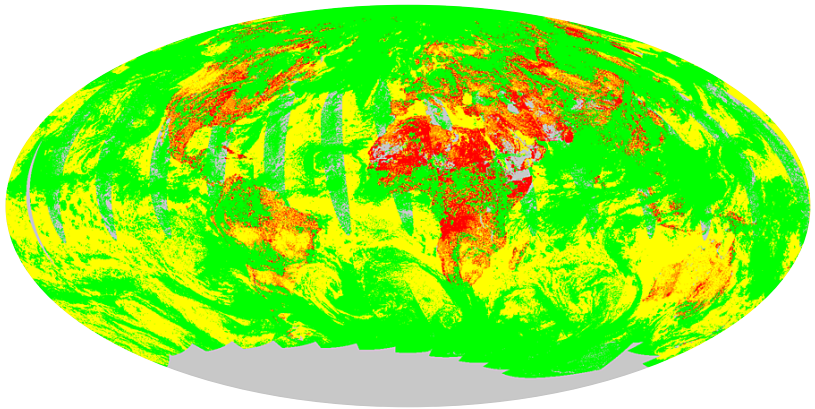
The global RGB (bands M5,M4,M3) browse of L2 VNP09, masked for all high – aerosols (left) and distribution of aerosol classes (QF7 Surface Reflectance, bits 2-3) are shown (right) . Consistent with Terra and Aqua, test shows more consistent and continuous retrieval, over the brighter surfaces





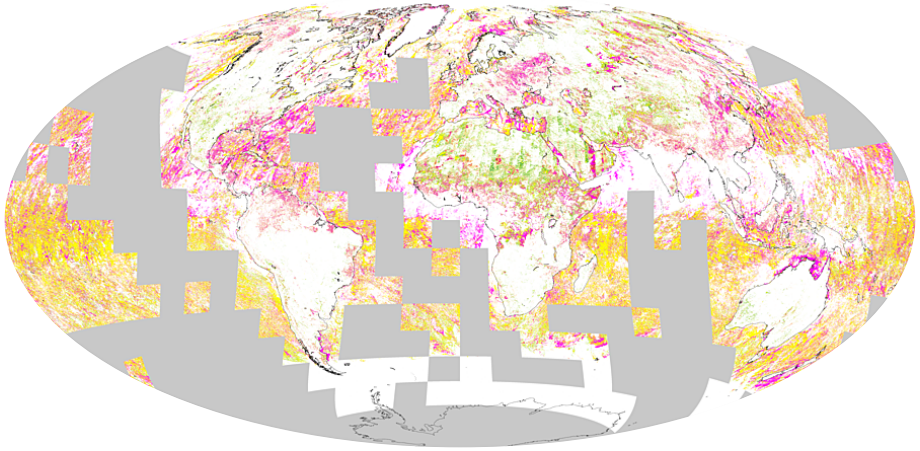
Baseline (AS 5000)





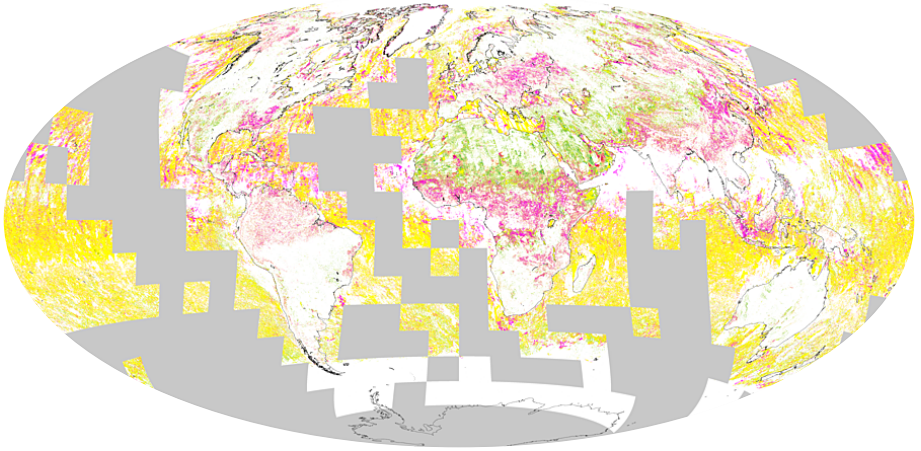
The 8-day Land Surface Reflectance products, MxD09A1, show significant localized impact with higher differences mainly observed along the tropical and mid-latitude regions.

Terra - MOD09A1

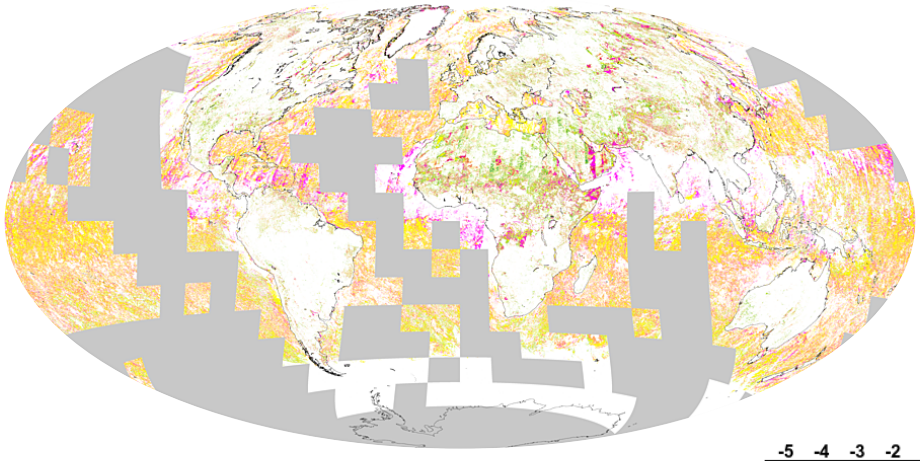


Relative Difference Image:
MOD09A1-Band1.A2018193

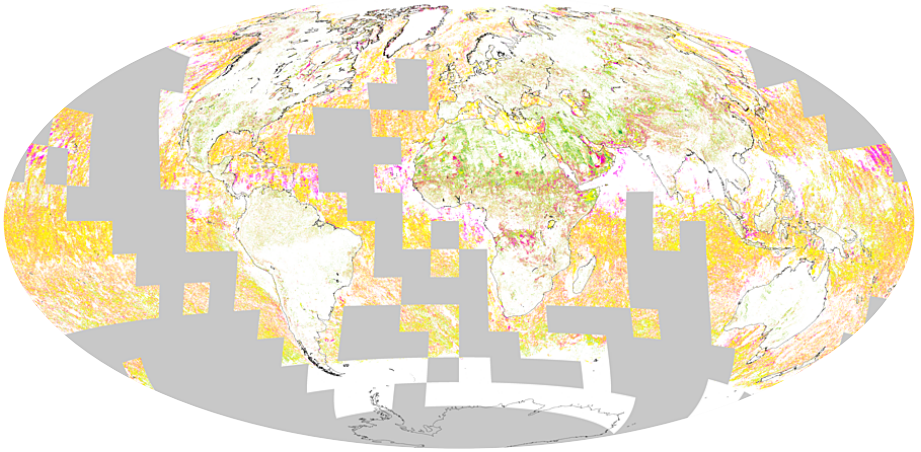
Aqua - MYD09A1



Relative Difference Image:
MYD09A1-Band1.A2018193



Relative Difference Image:
MOD09A1-Band2.A2018193

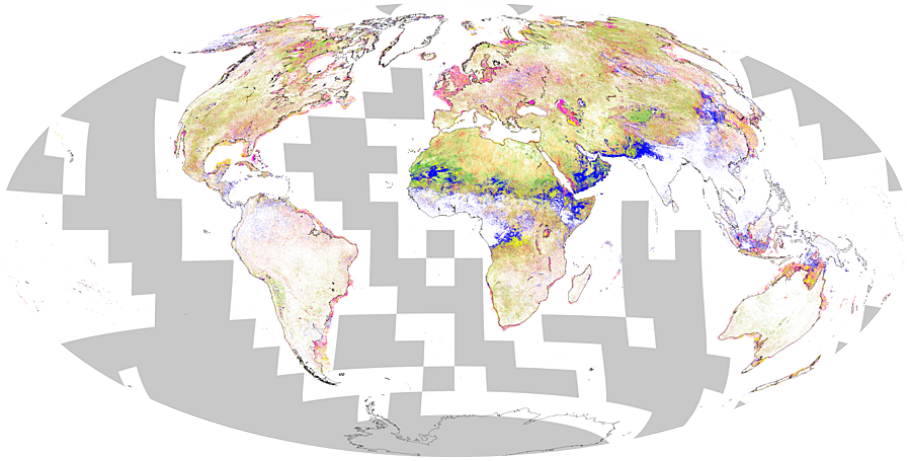


Relative Difference Image:
MYD09A1-Band2.A2018193

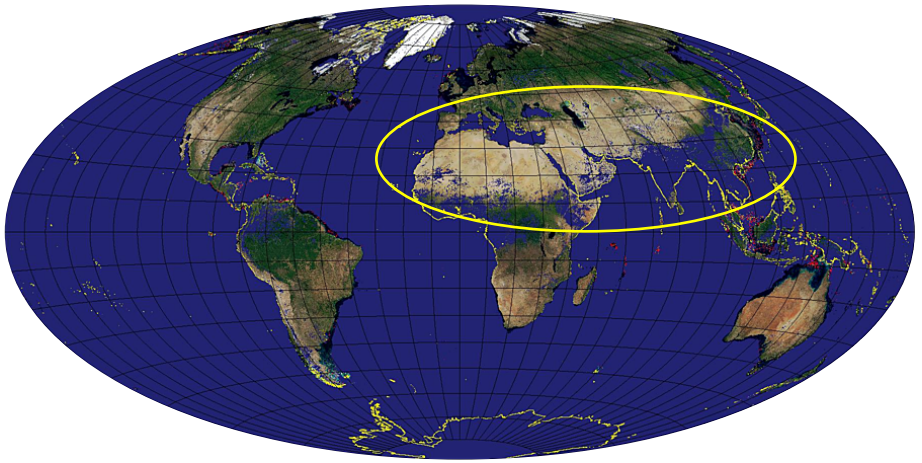
BRDF/Albedo

Similar pattern is seen for the downstream 500m and 1km Vegetation Index (VI) products (MxD13A1 and MxD13A2, respectively) and BRDF/Albedo (MCD43*) products, where in general, differences between 5-8% or less are seen over most of the globe, with much higher differences of 10% and above, seen over parts of Sahara, Arabian Peninsula, northern India, parts of northern and eastern China and south-central portions of North America. Almost all of these differences correspond to the change in aerosol categorization from high to low aerosol class, with the new revision. The BRDF/Albedo products now slightly more retrieval over the brighter surface areas in these regions (area within the yellow ellipse).

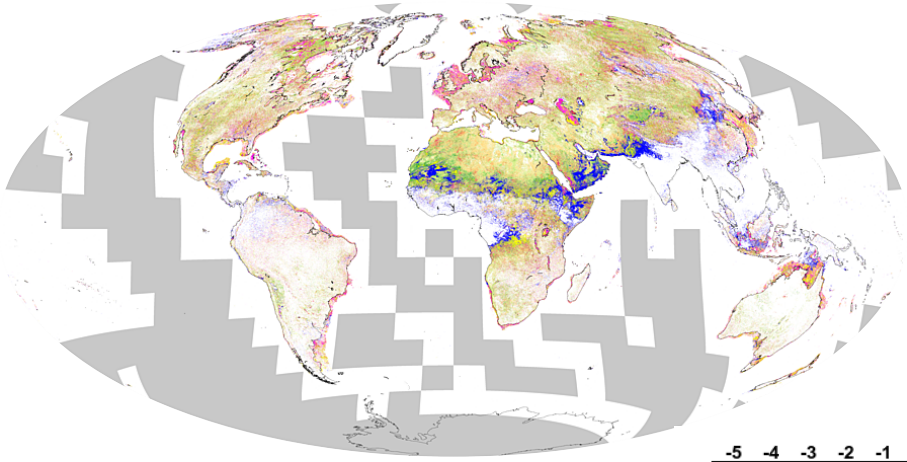
MODIS daily BRDF Parameters (MCD43A1)



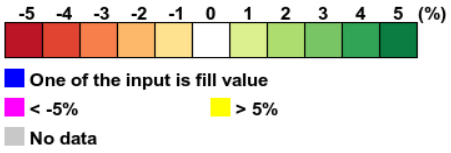
Relative Difference: MCD43A4-Band1.A2018193

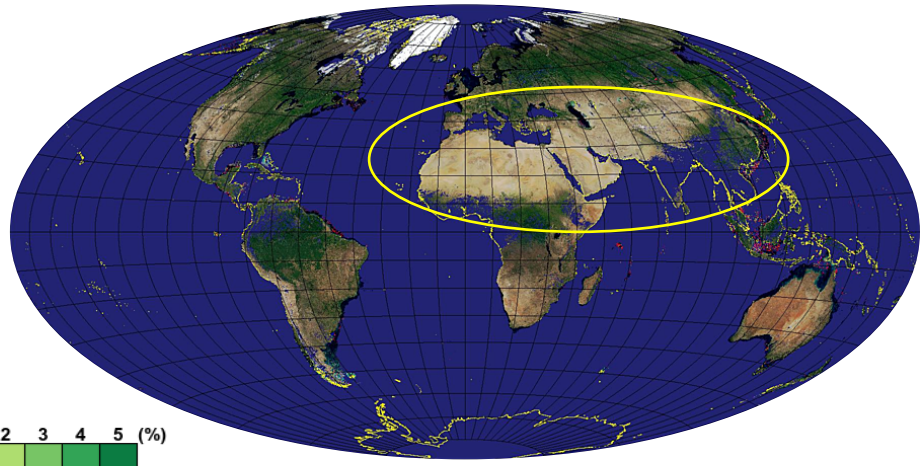


MCD43A1.A2018193-RGB - Baseline



Relative Difference: MCD43A4-Band2.A2018193

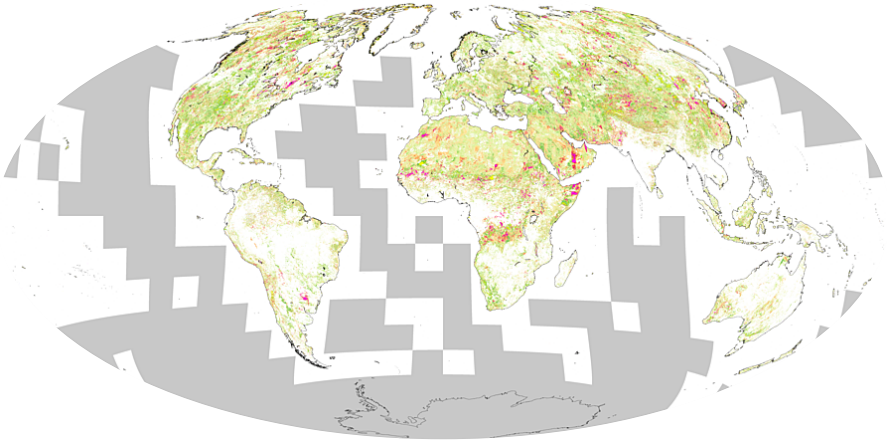




MCD43A1.A2018193-RGB - Test

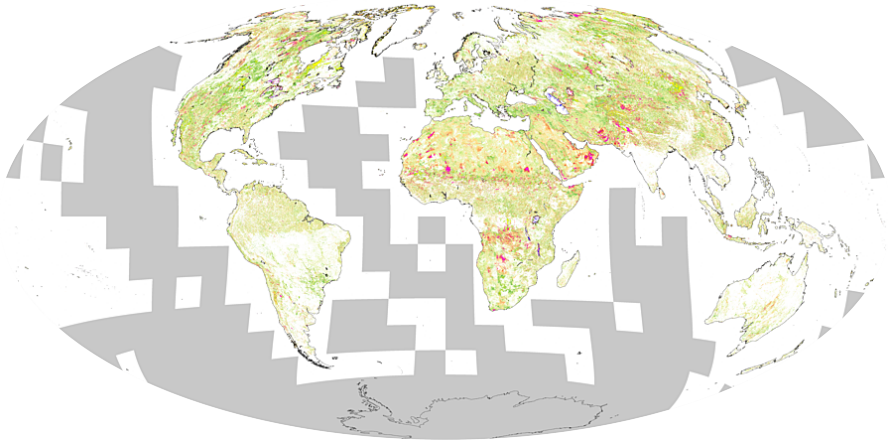
MODIS 16-day 500m VI (MxD13A1)

Terra – MOD13A1

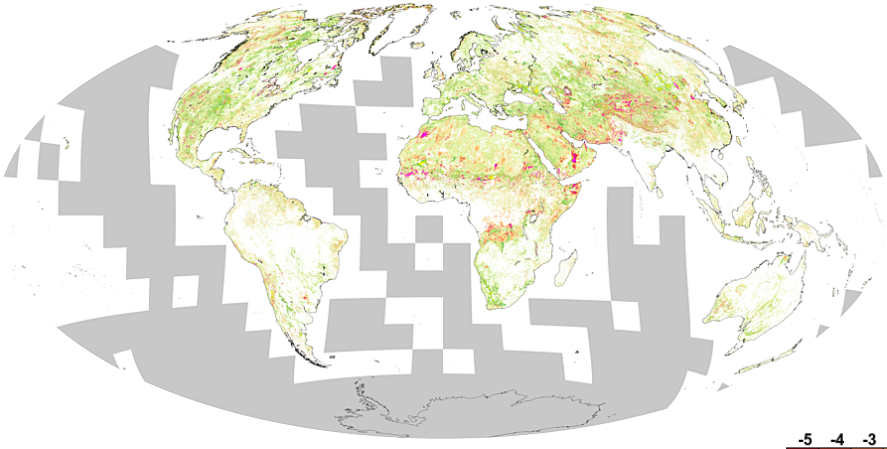


Relative Difference Image: EVI
2018193

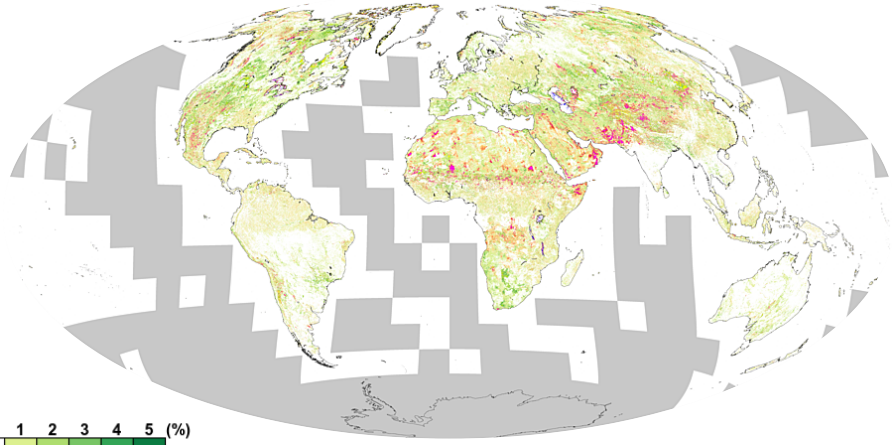
Aqua – MYD13A1



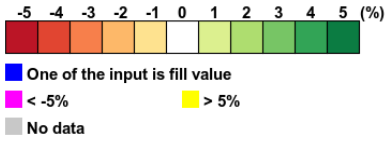
Relative Difference Image: EVI
2018185



Relative Difference Image: NDVI
2018193



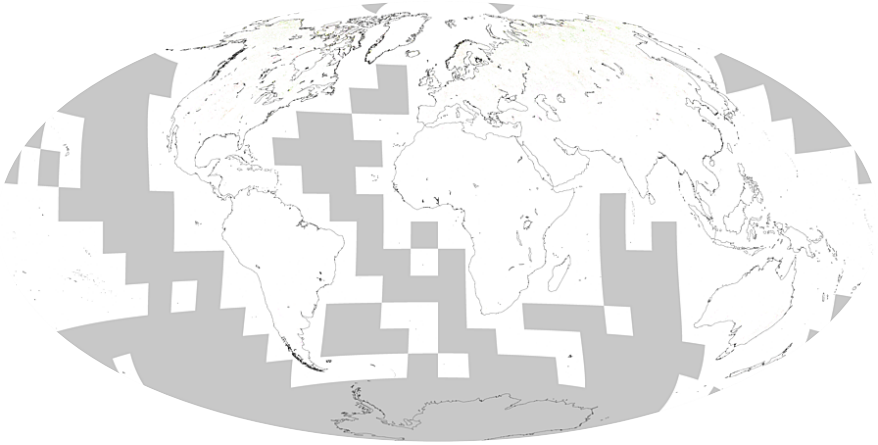
Relative Difference Image: NDVI
2018185



MODIS 8-day 500m Lai/Fpar (MxD15A2)

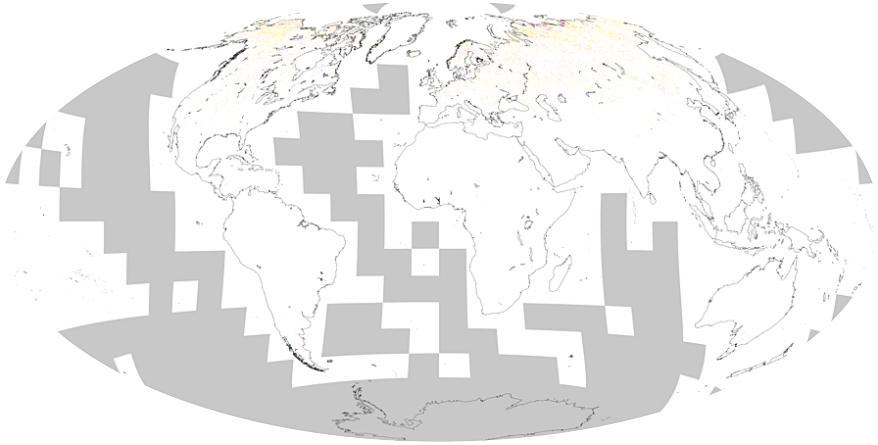
The change in aerosol flag, is seen to have minimal impact on the MxD15A2 products, as can be seen from the difference between the test and baseline for Fpar (upper panel) and Lai (lower panel), for Terra and Aqua, respectively. The input daily L2G Lite MxD09GA files does show improvements, in the revised test version but somehow, the daily Lai/Fpar retrieval algorithm (MXD15A1) may not be heavily weighing on the aerosol loading category of the observations.

MOD15A2H

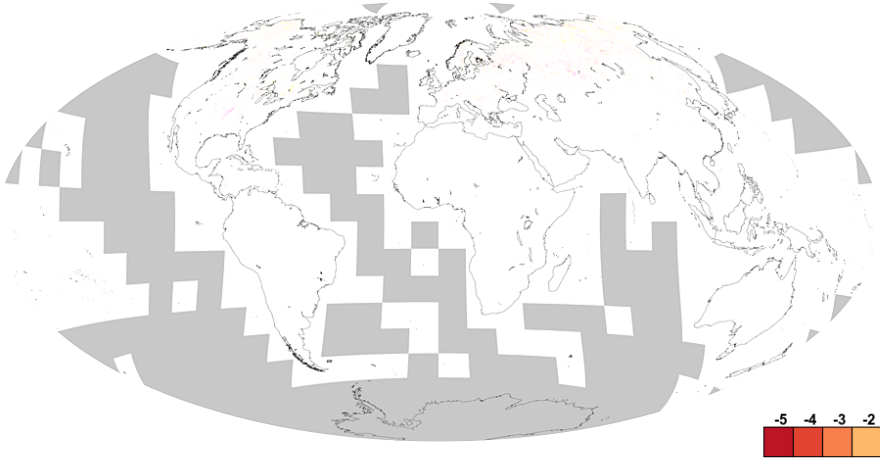


Relative Difference Image: FPAR
2018193

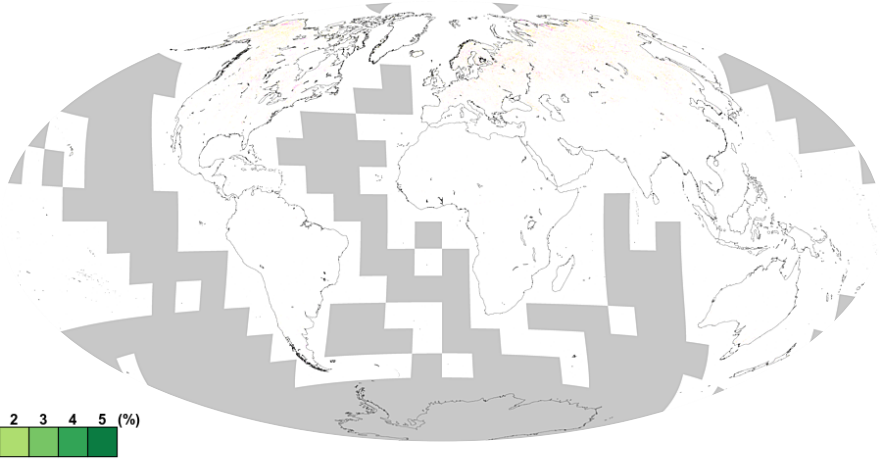
MYD15A2H



Relative Difference Image: Fpar
2018193



Relative Difference Image: LAI
2018193



Relative Difference Image: LAI
2018193

Tile based differences over some selected global tiles.

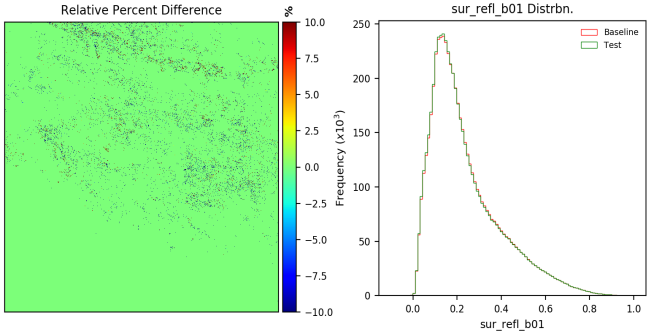
All tile-based analysis has been carried out for the following products:

- 8-day Land Surface Reflectance – MxD09A1
- 8-day 500m Lai/Fpar (MxD15A2)
- 16-day 500m VI (MxD13A1)
- Daily combined Terra+Aqua BRDF NBAR reflectance (MCD43A4)

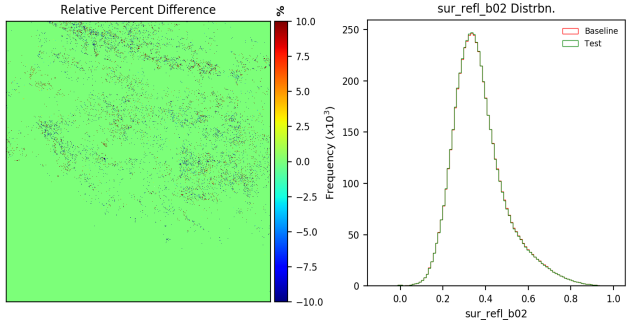
Terra h25v06

Distribution of aerosol classes in baseline and test:
0 - Climatology, 1 - Low, 2 - Average, 3 - High

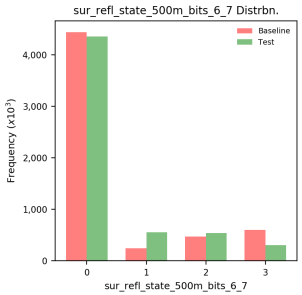
MOD09A1.A2018193.h25v06.061
sur_refl_b01



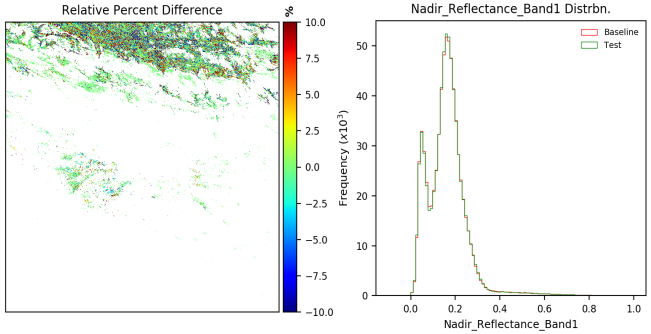
MOD09A1.A2018193.h25v06.061
sur_refl_b02



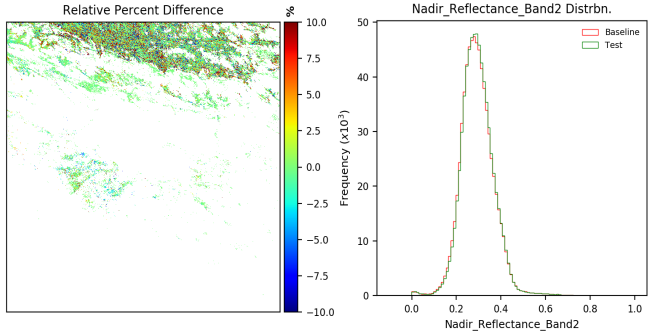
MOD09A1.A2018193.h25v06.061
sur_refl_state_500m_bits_6_7



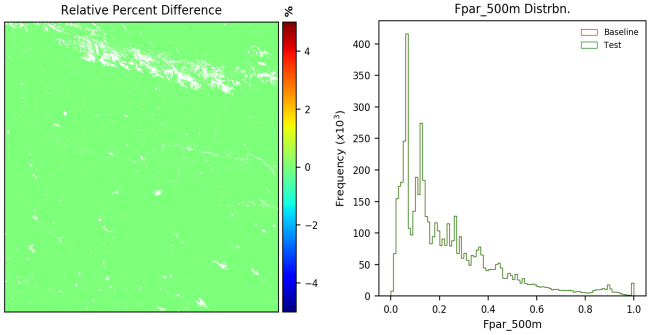
MCD43A4.A2018193.h25v06.061
Nadir_Reflectance_Band1



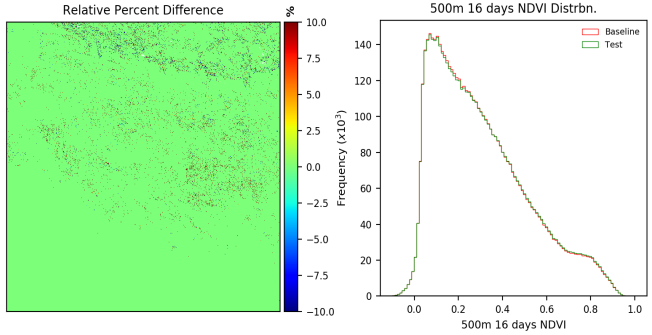
MCD43A4.A2018193.h25v06.061
Nadir_Reflectance_Band2



MOD15A2H.A2018193.h25v06.061
Fpar_500m

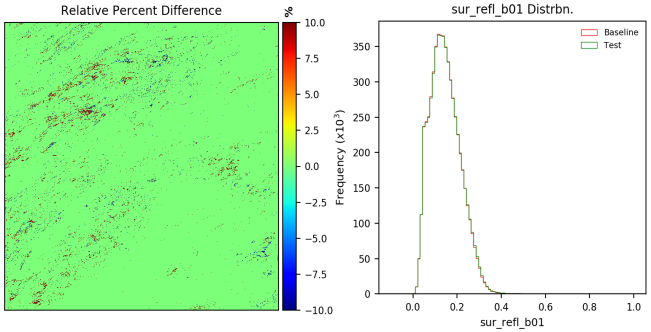


MOD13A1.A2018193.h25v06.061
500m 16 days NDVI

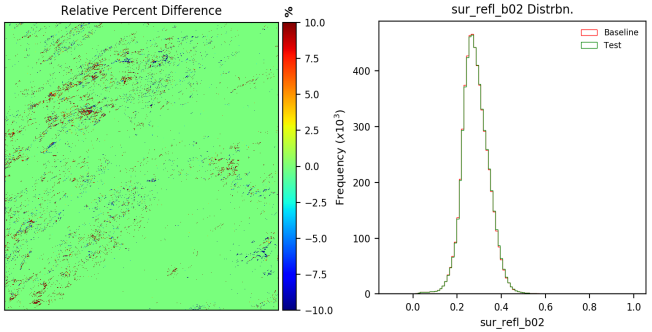


Terra h09v05

MOD09A1.A2018193.h09v05.061
sur_refl_b01

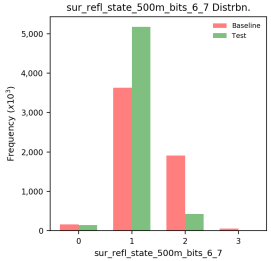


MOD09A1.A2018193.h09v05.061
sur_refl_b02

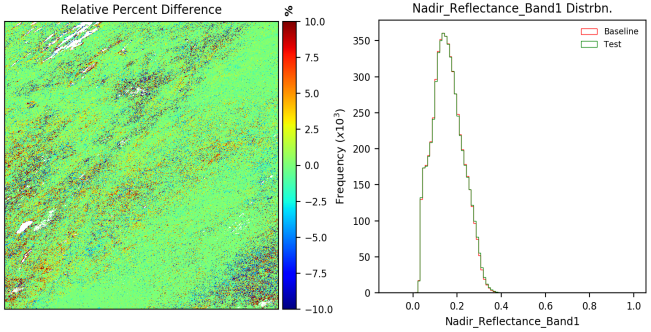


Distribution of aerosol classes in baseline and test:
0 - Climatology, 1 - Low, 2 - Average, 3 - High

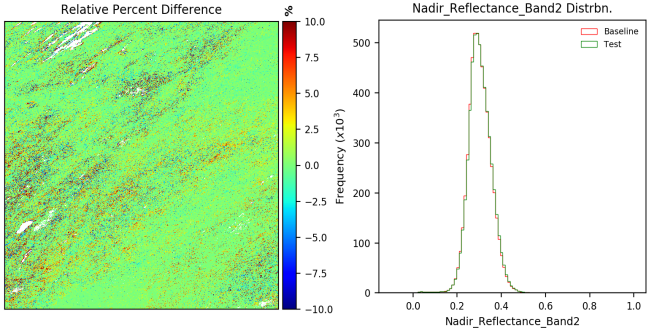
MOD09A1.A2018193.h09v05.061
sur_refl_state_500m_bits_6_7



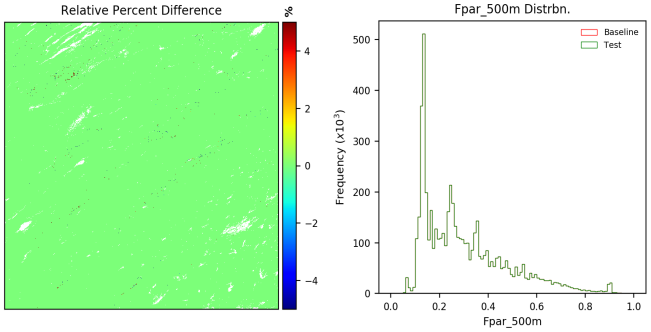
MCD43A4.A2018193.h09v05.061
Nadir_Reflectance_Band1



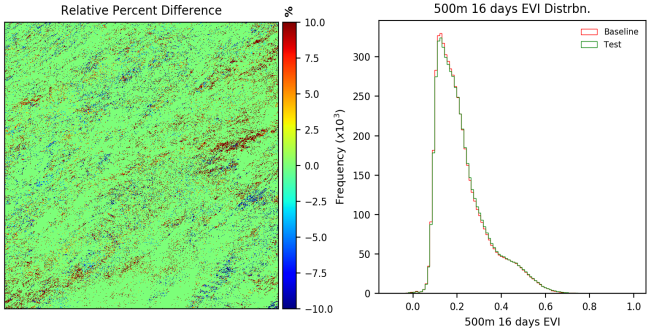
MCD43A4.A2018193.h09v05.061
Nadir_Reflectance_Band2



MOD15A2H.A2018193.h09v05.061
Fpar_500m



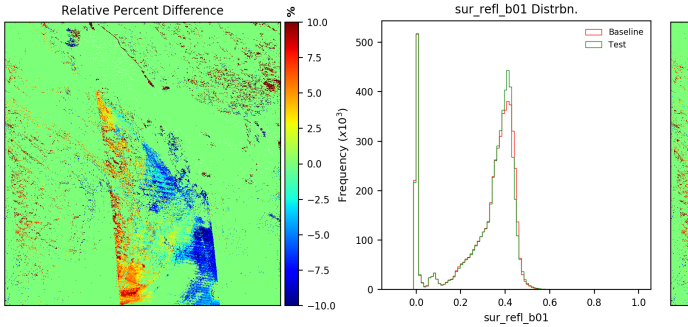
MOD13A1.A2018193.h09v05.061
500m 16 days EVI



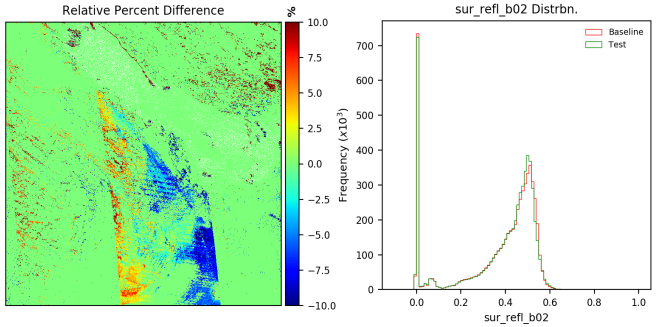
Terra h22v06

Distribution of aerosol classes in baseline and test:
0 - Climatology, 1 - Low, 2 - Average, 3 - High

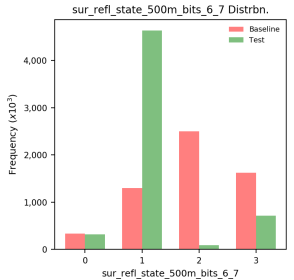
MOD09A1.A2018193.h22v06.061
sur_refl_b01



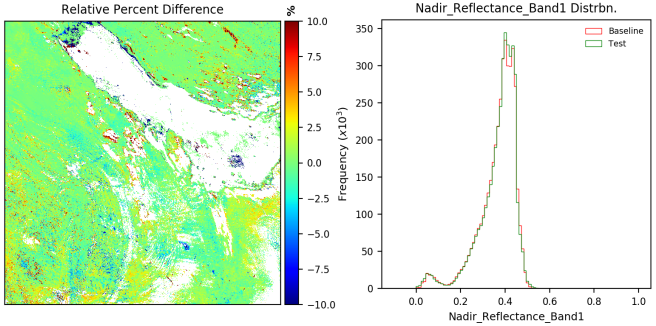
MOD09A1.A2018193.h22v06.061
sur_refl_b02



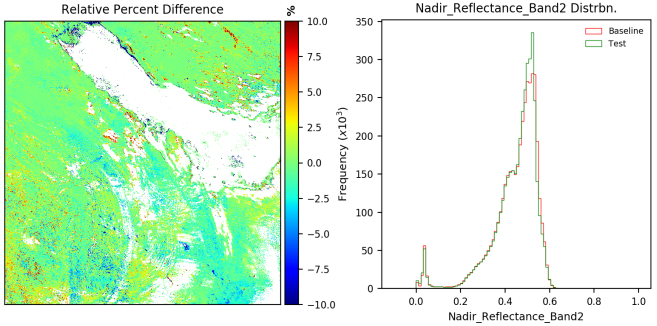
MOD09A1.A2018193.h22v06.061
sur_refl_state_500m_bits_6_7



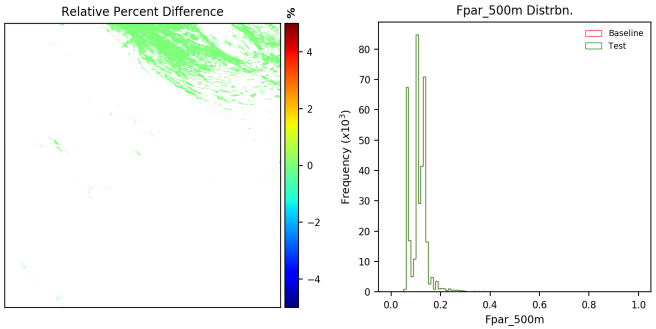
MCD43A4.A2018193.h22v06.061
Nadir_Reflectance_Band1



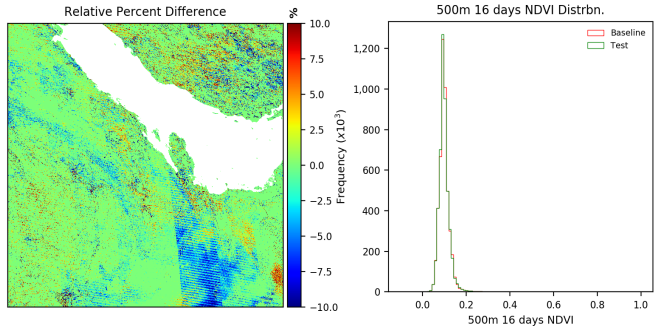
MCD43A4.A2018193.h22v06.061
Nadir_Reflectance_Band2



MOD15A2H.A2018193.h22v06.061
Fpar_500m

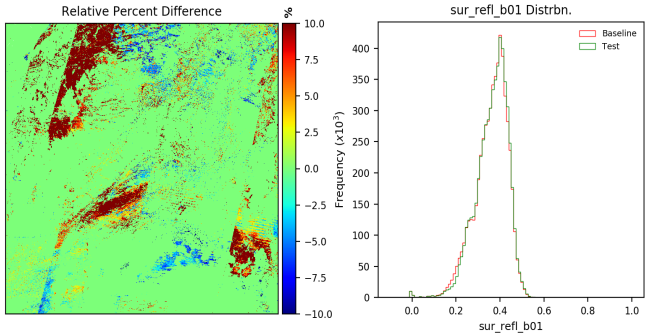


MOD13A1.A2018193.h22v06.061
500m 16 days NDVI

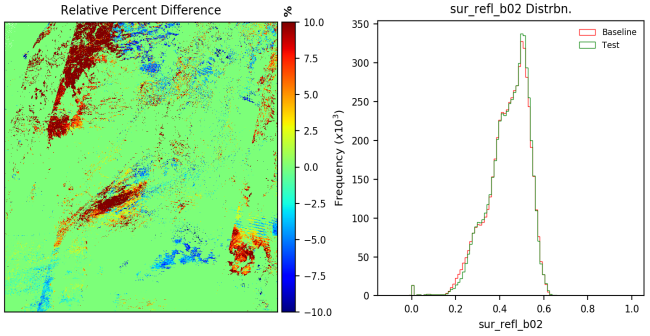


Terra h17v06

MOD09A1.A2018193.h17v06.061
sur_refl_b01

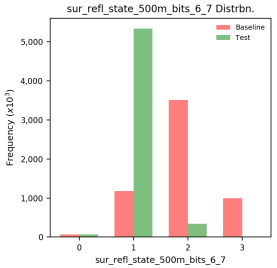


MOD09A1.A2018193.h17v06.061
sur_refl_b02

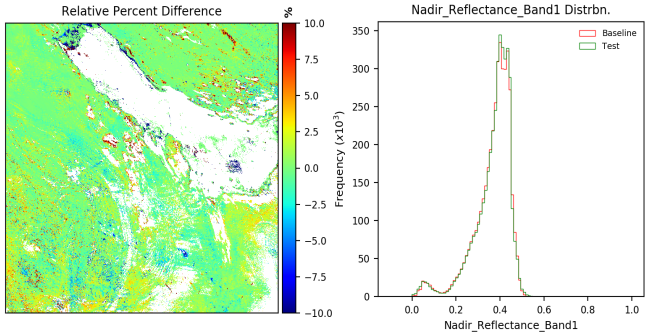


Distribution of aerosol classes in baseline and test:
0 - Climatology, 1 - Low, 2 - Average, 3 - High

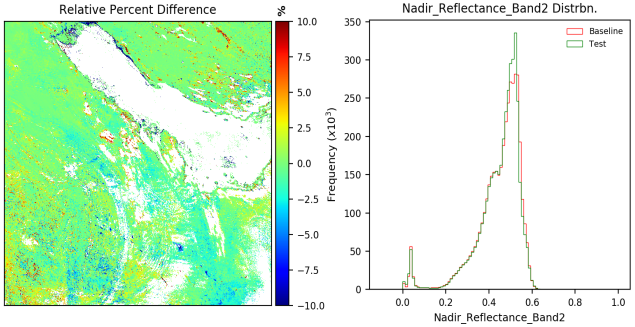
MOD09A1.A2018193.h17v06.061
sur_refl_state_500m_bits_6_7



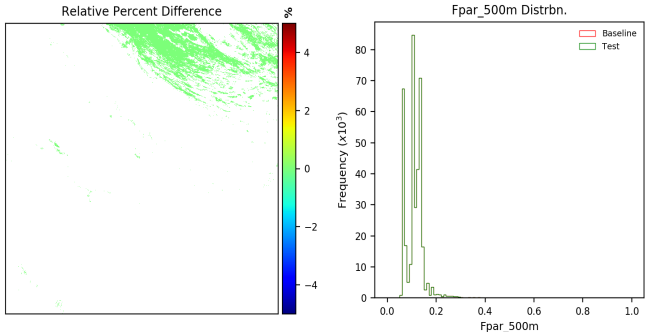
MCD43A4.A2018193.h22v06.061
Nadir_Reflectance_Band1



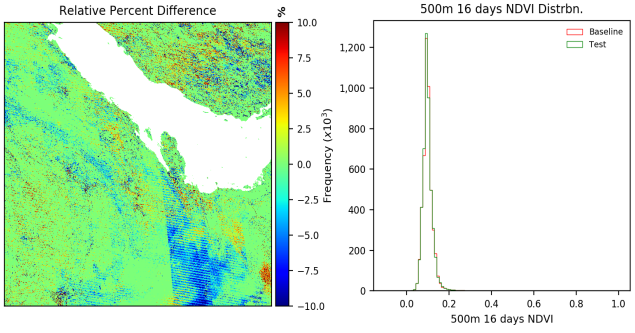
MCD43A4.A2018193.h22v06.061
Nadir_Reflectance_Band2



MOD15A2H.A2018193.h22v06.061
Fpar_500m

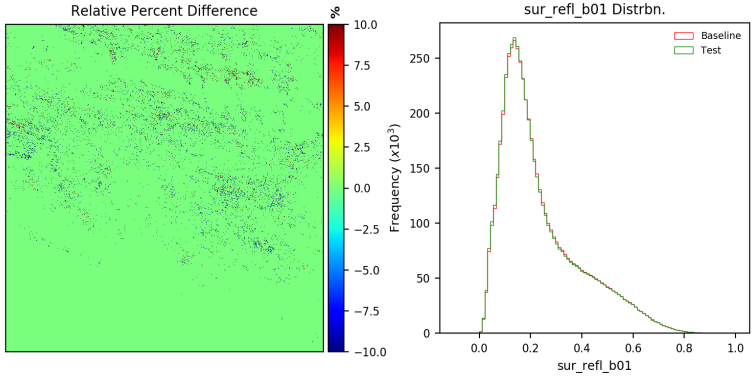


MOD13A1.A2018193.h22v06.061
500m 16 days NDVI

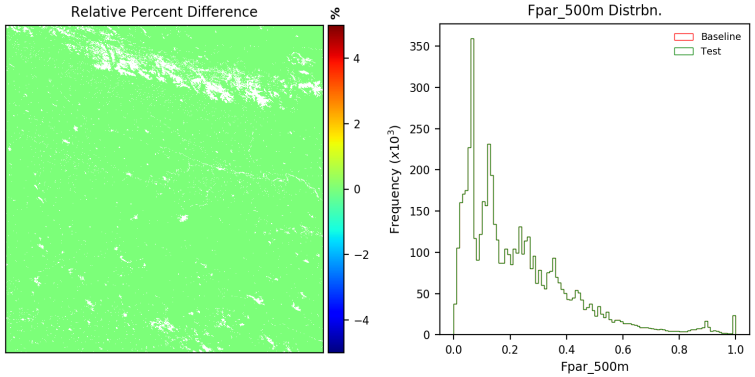


Aqua H25v06

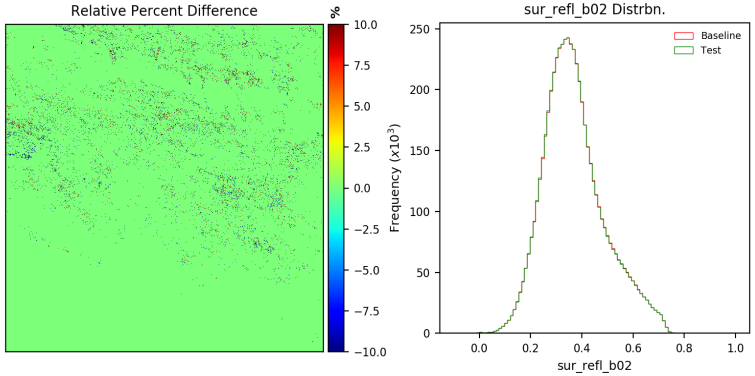
MYD09A1.A2018193.h25v06.061
sur_refl_b01



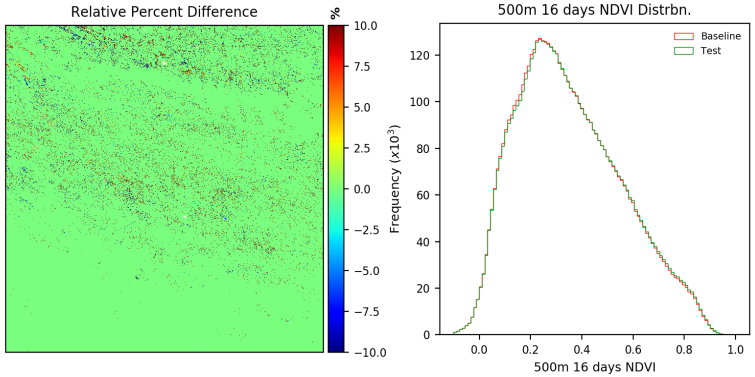
MYD15A2H.A2018193.h25v06.061
Fpar_500m



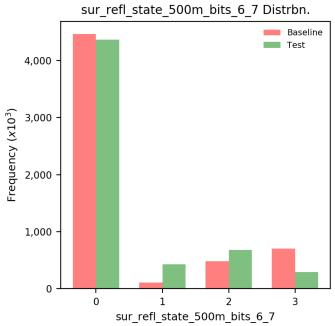
MYD09A1.A2018193.h25v06.061
sur_refl_b02



MYD13A1.A2018185.h25v06.061
500m 16 days NDVI



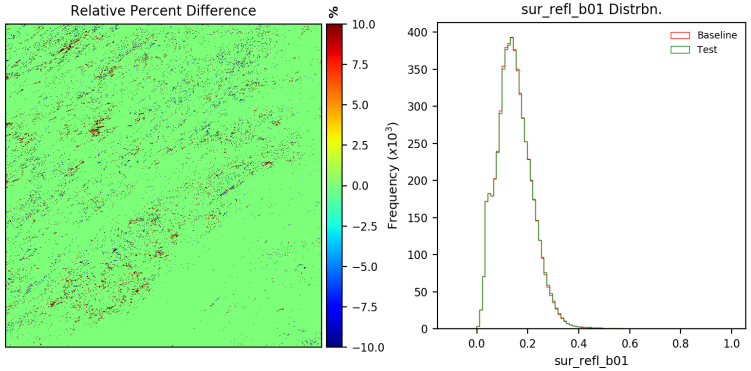
MYD09A1.A2018193.h25v06.061
sur_refl_state_500m_bits_6_7



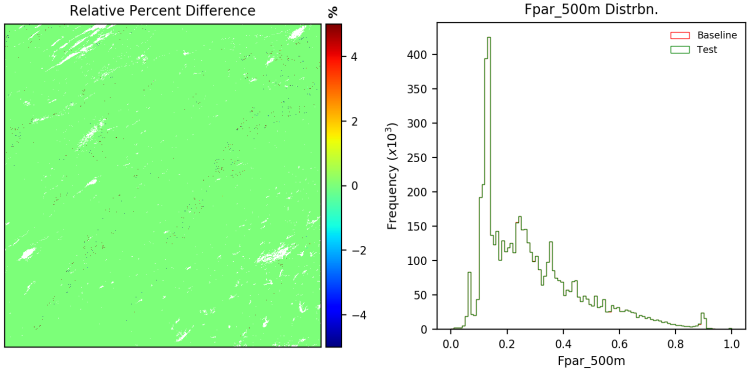
Distribution of aerosol classes in baseline and test:
0 - Climatology, 1 - Low, 2 - Average, 3 - High

Aqua H09v05

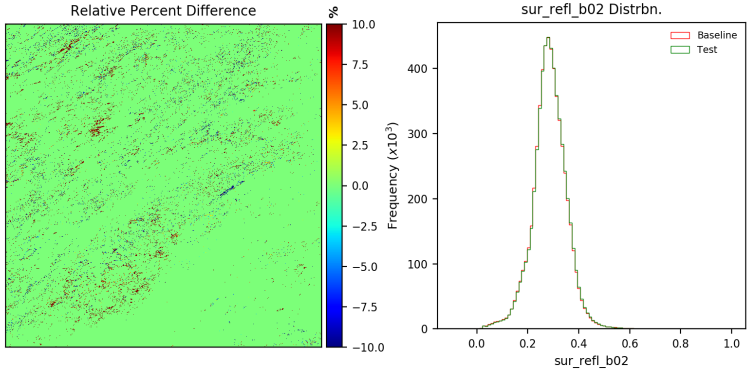
MYD09A1.A2018193.h09v05.061
sur_refl_b01



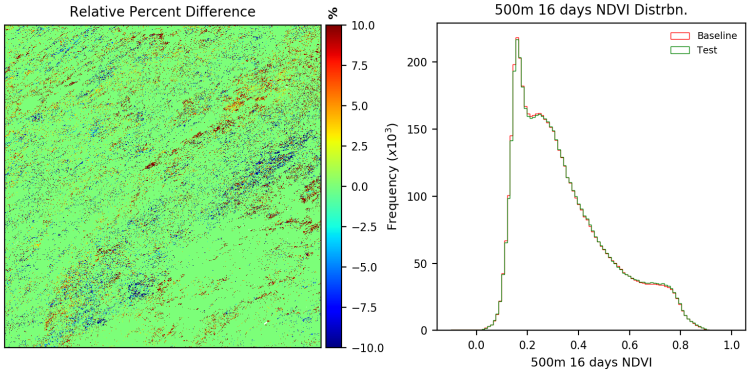
MYD15A2H.A2018193.h09v05.061
Fpar_500m



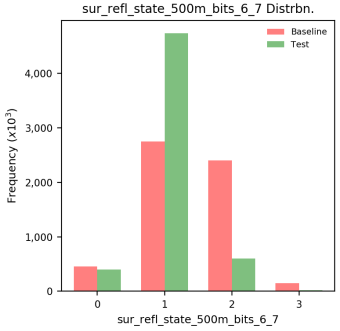
MYD09A1.A2018193.h09v05.061
sur_refl_b02



MYD13A1.A2018185.h09v05.061
500m 16 days NDVI



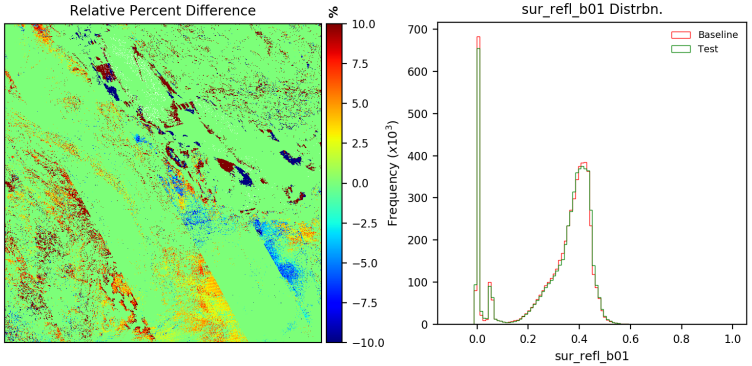
MYD09A1.A2018193.h09v05.061
sur_refl_state_500m_bits_6_7



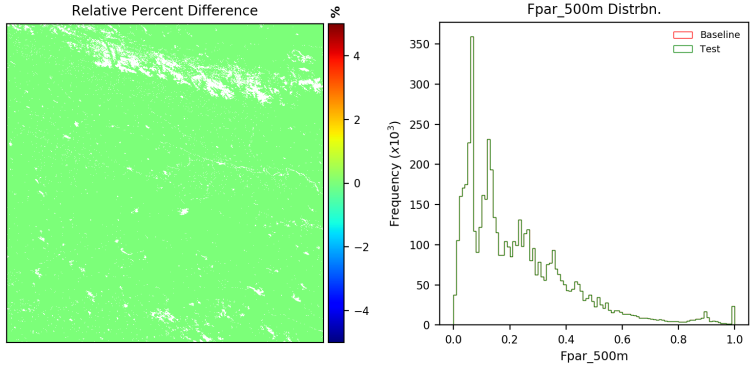
Distribution of aerosol classes in baseline and test:
0 - Climatology, 1 - Low, 2 - Average, 3 - High

Aqua H22v06

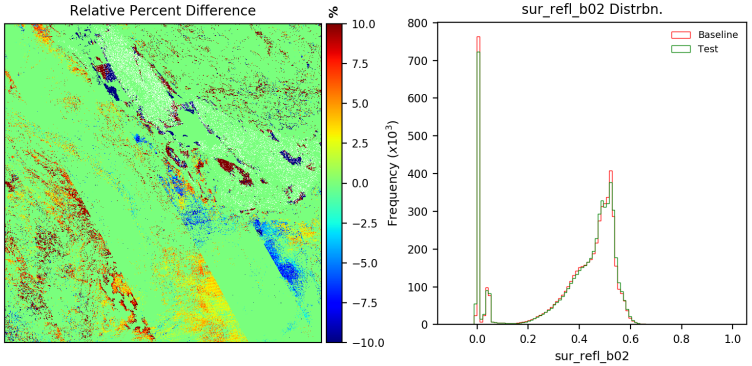
MYD09A1.A2018193.h22v06.061
sur_refl_b01



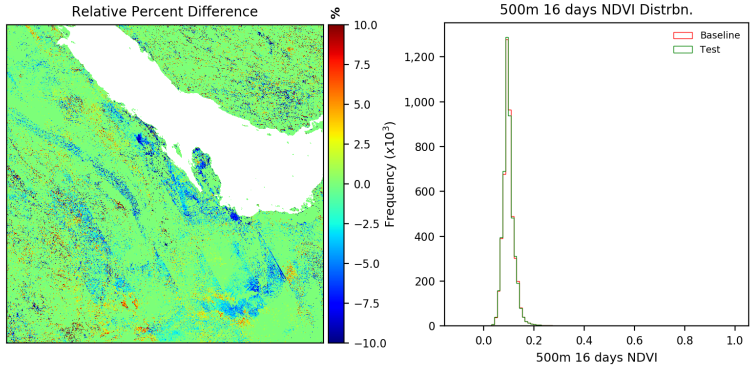
MYD15A2H.A2018193.h25v06.061
Fpar_500m



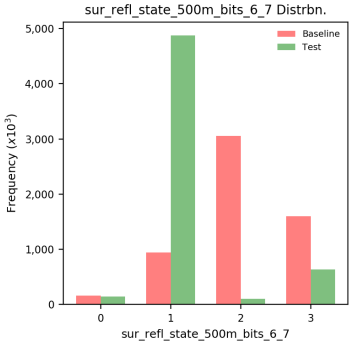
MYD09A1.A2018193.h22v06.061
sur_refl_b02



MYD13A1.A2018185.h22v06.061
500m 16 days NDVI



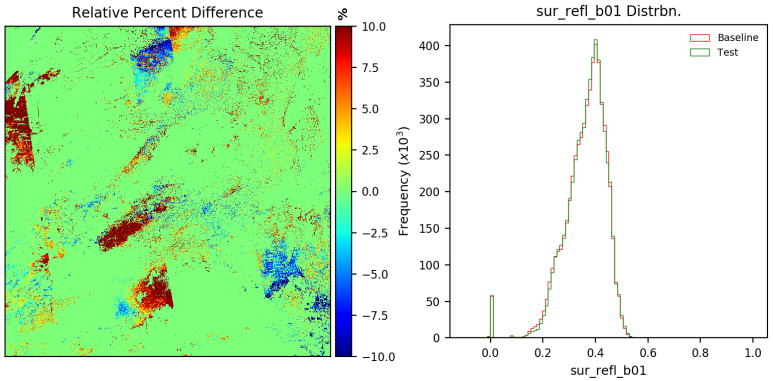
MYD09A1.A2018193.h22v06.061
sur_refl_state_500m_bits_6_7



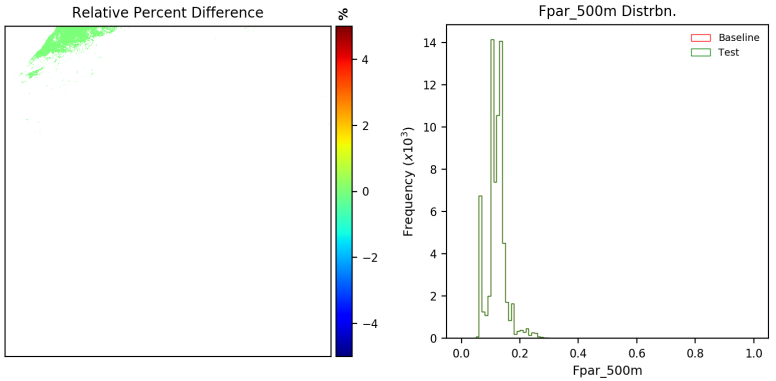
Distribution of aerosol classes in baseline and test:
0 - Climatology, 1 - Low, 2 - Average, 3 - High

Aqua H17v06

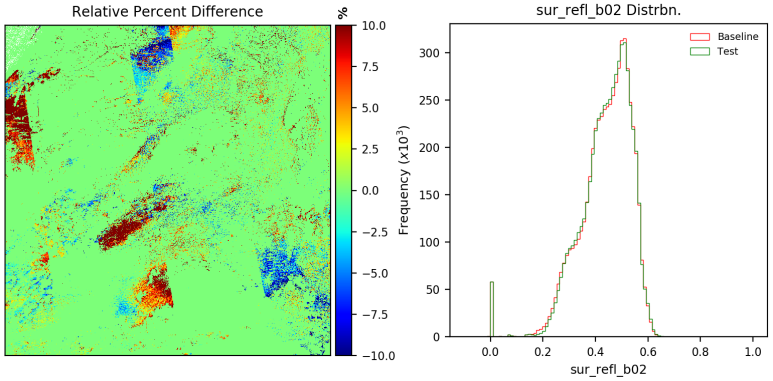
MYD09A1.A2018193.h17v06.061
sur_refl_b01



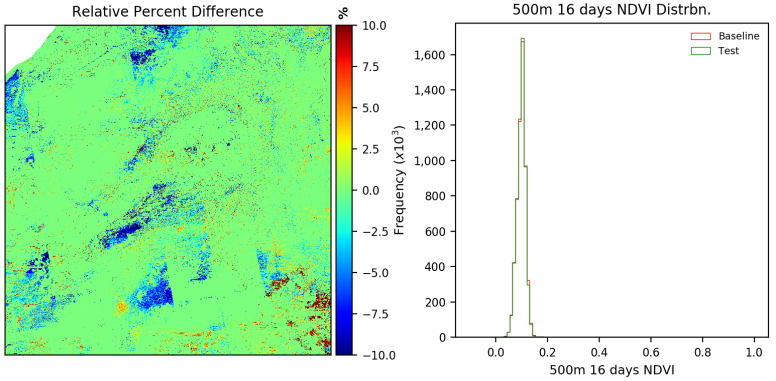
MYD15A2H.A2018193.h17v06.061
Fpar_500m



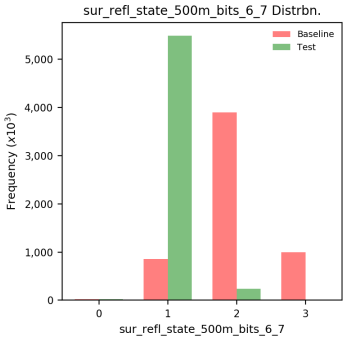
MYD09A1.A2018193.h17v06.061
sur_refl_b02



MYD13A1.A2018185.h17v06.061
500m 16 days NDVI



MYD09A1.A2018193.h17v06.061
sur_refl_state_500m_bits_6_7



Distribution of aerosol classes in baseline and test:
0 - Climatology, 1 - Low, 2 - Average, 3 - High