Assessment of MODIS and VIIRS Calibration Consistency for RSB Using Vicarious Approaches

MODIS and VIIRS Characterization Support Team, NASA/GSFC
(presented by Aisheng Wu)

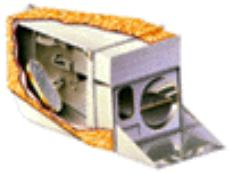
MODIS/VIIRS Calibration Workshop (Virtual), February 25-26, 2021

Outline

- Introduction
- Methodology
  - Vicarious approaches (SNO, desert, Dome C and DCC)
- Results
  - Terra and Aqua MODIS
  - SNPP and NOAA-20 VIIRS
  - NOAA-20 VIIRS and Aqua MODIS
- Summary

Calibration inter-comparison results from lunar observations are also included

MODIS and VIIRS



Spectrally Matched RSB (µm)

VIIRS			MODIS		
Band	CW	BW	Band	CW	BW
M1	412	20	B8	412	15
M2	445	18	B9	443	10
M3	488	20	B10	488	10
M4	555	20	B4	555	20
M5	672	20	B1	645	50
M6	746	15	B15	748	10
M7	865	39	B2	858	35
M8	1240	20	B5	1240	20
M9	1378	15	B26	1375	30
M10	1610	60	B6	1640	24
M11	2250	50	B7	2130	50
I1	640	80	B1	645	50
I2	865	39	B2	858	35
I3	1610	60	B6	1640	24

Terra/Aqua MODIS

- Scanning radiometer
- 36 bands between 0.4 and 14 µm
- Morning/afternoon polar orbits
- Swath distance of 2330 km
- Nadir resolutions: 0.25, 0.5, 1.0 km
- Launched Dec 1999 & May 2002

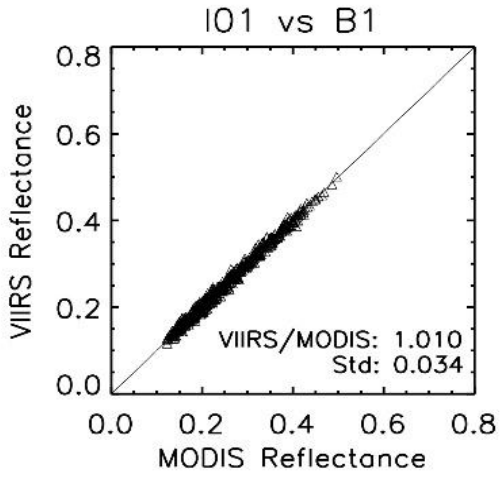
SNPP/NOAA-20 VIIRS

- Scanning radiometer
- 22 bands between 0.4 and 12 µm
- Afternoon polar orbit
- Swath distance of 3000 km
- Nadir resolutions: 0.375, 0.750 km
- RTA, dual-gain

Methodology

Simultaneous Nadir Overpasses (SNO)

- Either MODIS or VIIRS used as a transfer radiometer. TOA reflectance ratio between MODIS/VIIRS from high-latitude SNO (<30 seconds, two-line element), once every 3-4 days
- No BRDF correction applied
- Correction for RSR mismatch based on a scene-averaged SCIAMACHY hyperspectral profile over typical high-latitude
- Larger uncertainties in the SWIR bands (compared to the VIS/NIR bands) likely due to their high sensitivity to atmospheric conditions



Pixel-by-pixel match from SNO on Oct 8, 2019

Methodology

Pseudo-Invariant Calibration Sites (PICS):

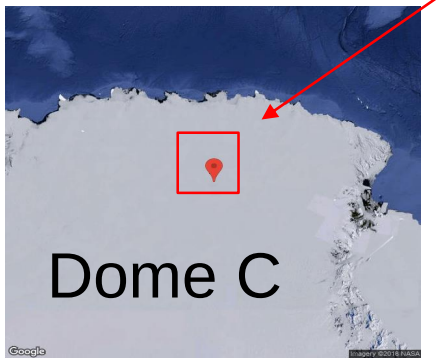
- PICS approaches include desert (Libya 4) and Dome C
- Near-nadir, 16-day repeatable orbits for desert, daily overpasses for Dome C in Antarctic summer.
- Target area of 20 x 20 km. Employ semi-empirical (desert) and empirical (Dome C) BRDF correction. BRDF coefficients derived first several years of on-orbit measurements

DCC approach:

- DCC pixels collected over western tropical Pacific. *Mu et al. "Optimization of a Deep Convective Cloud Technique in Evaluating the Long-Term Radiometric Stability of MODIS Reflective Solar Bands", Remote Sensing, vol. 9 (6), issue 535, 2017.*

RSR correction: RSR mismatch between the two sensors accounted using historic SCIAMACHY hyperspectral profiles

20 x 20 km

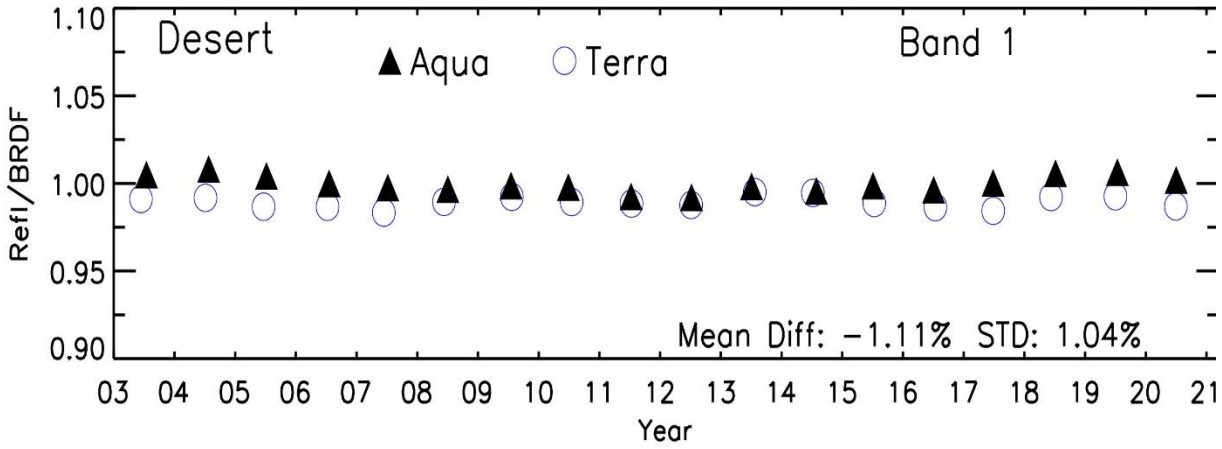


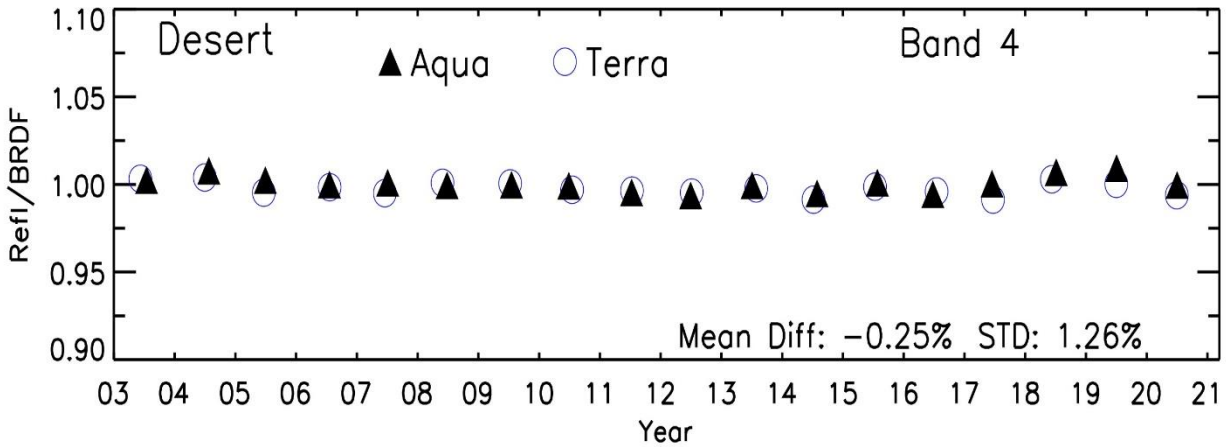
Data version conversion

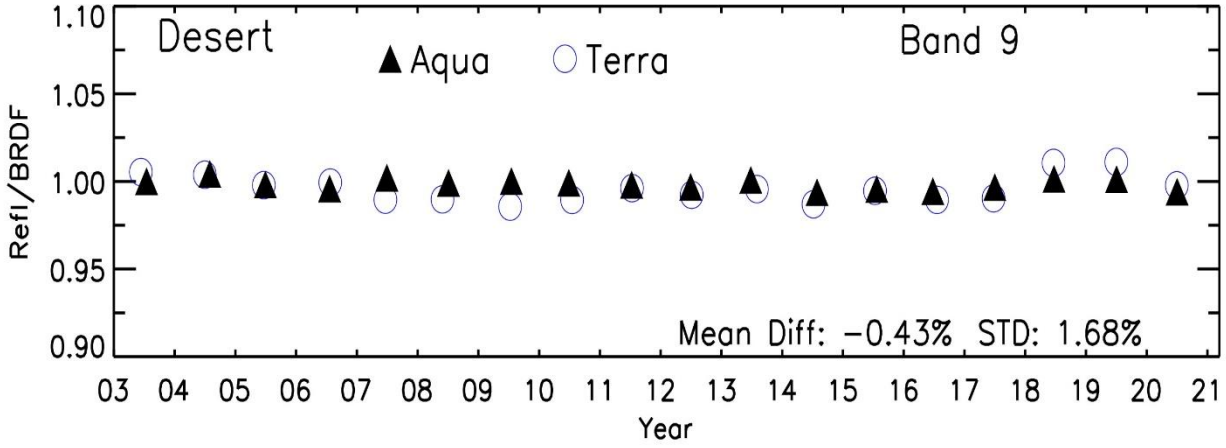
Data Version and Scaling

- Aqua and Terra MODIS Collection 6.1
- SNPP Collection 1 L1B
  - Collection 2 (C2) has notable improvements for a few RSB (L1B LSIPS for validation, not released official)
  - An F-factor LUT (instrument gain) scaling ratio between C1 and C2 is used to scale the time-series to provide the assessment using the most recent products
- N20 Collection 2 L1B
  - No scaling applied as C2 only has minor differences (<0.1%) included in C2.1 for RSB

Terra and Aqua RSB consistency (desert)

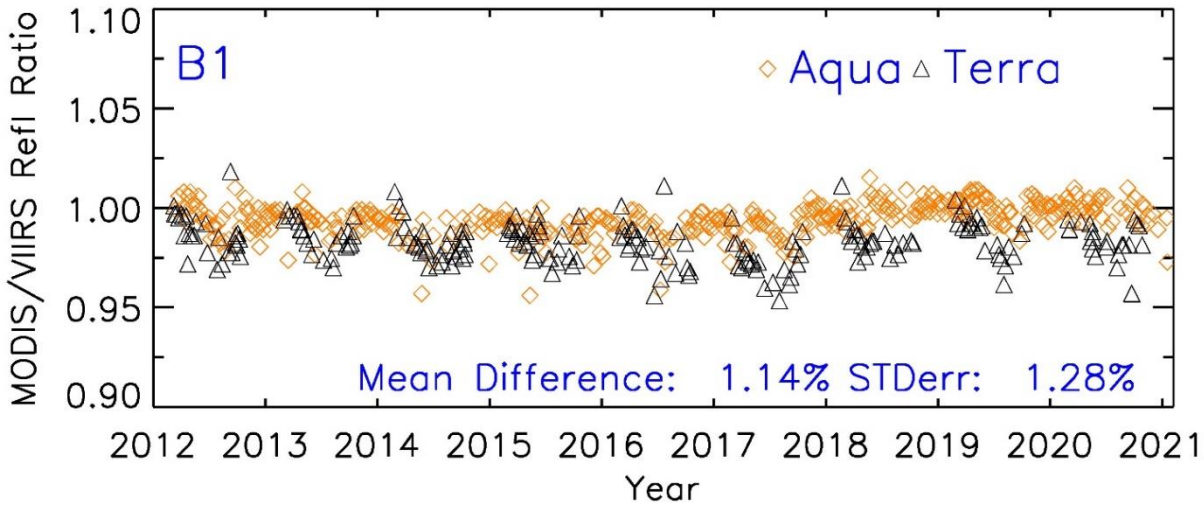


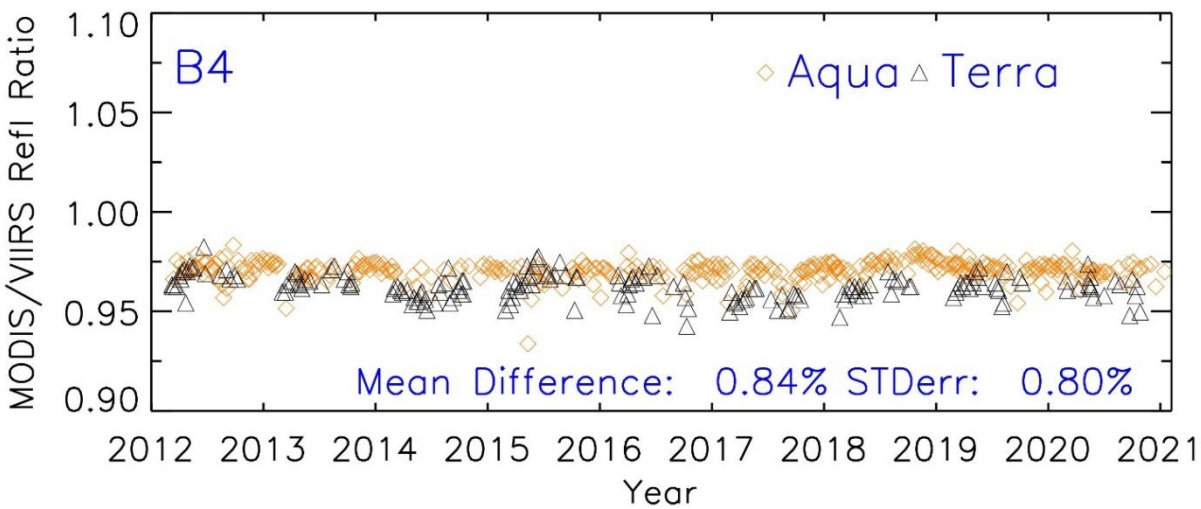


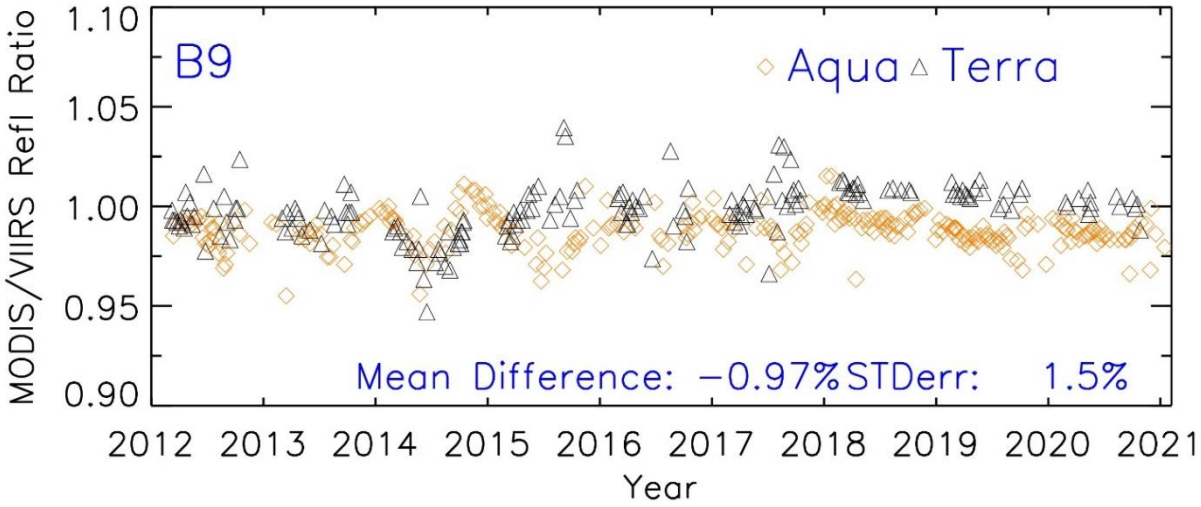


Excellent stability for C6.1 and Terra and Aqua differences are within 2% for all RSB.

Terra and Aqua RSB consistency (SNO)

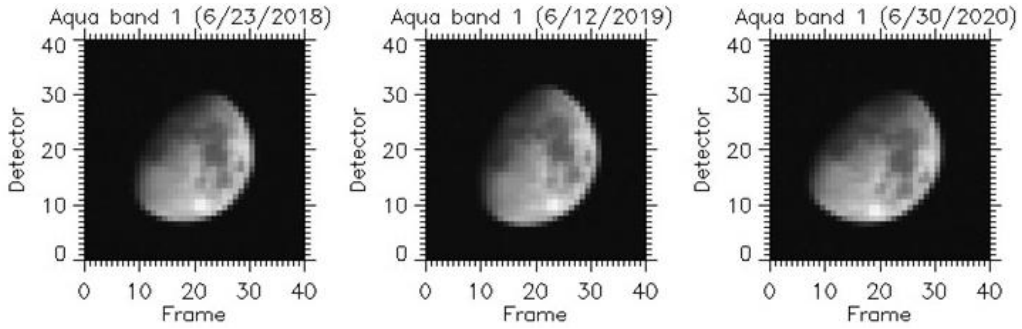




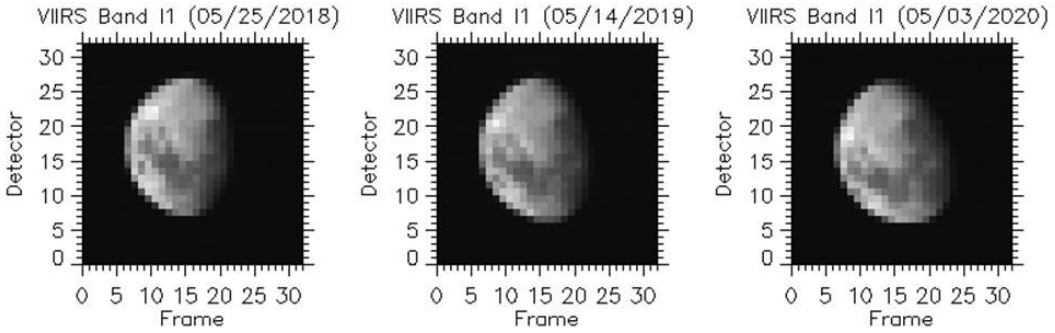


Results are based on Terra/Aqua and SNPP SNO. Terra data gaps are due to exclusion of SZ > 80°. Terra and Aqua differences are within 2% for all RSB.

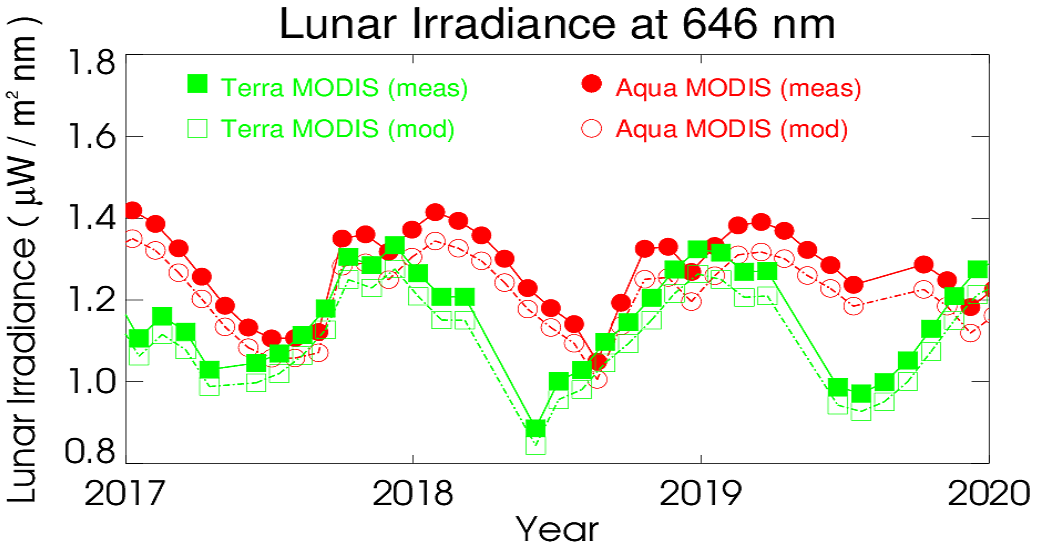
Calibration Inter-comparison Using the Moon



Aqua MODIS band 1 lunar images



S-NPP VIIRS band I1 lunar images



$$(I_{A_Meas}/I_{A_Model})/(I_{B_Meas}/I_{B_Model})$$

I_{A_Meas} and I_{B_Meas}: Integrated lunar irradiance measured by sensor A and B

I_{A_Model} and I_{B_Model}: Integrated lunar irradiance from ROLO for sensor A and B

X. Xiong et al, GRSL 2008

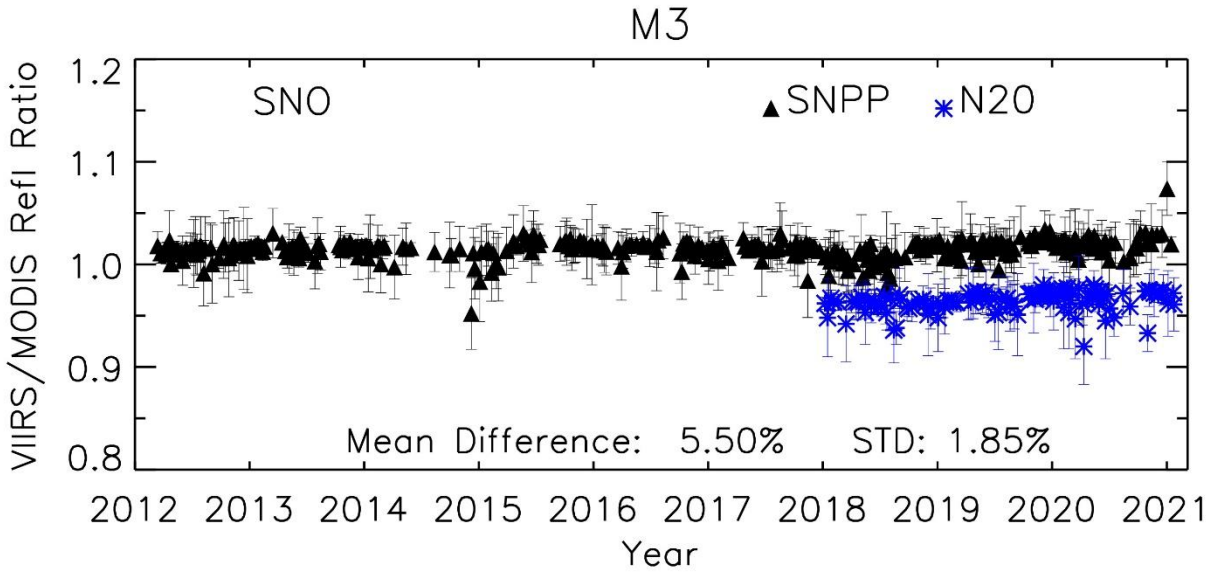
Terra and Aqua RSB consistency

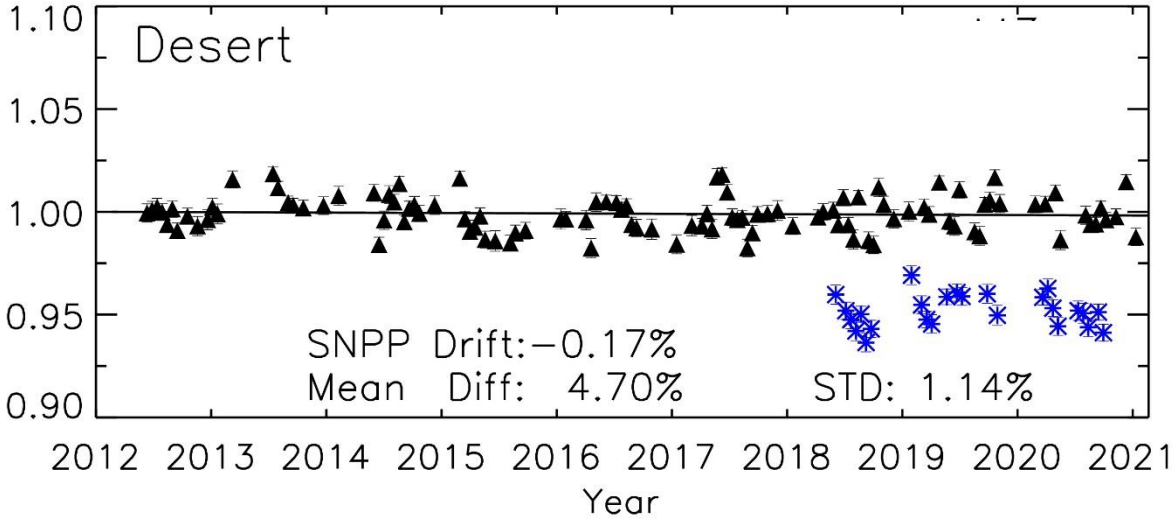
Terra and Aqua RSB comparison (Terra – Aqua) (%)

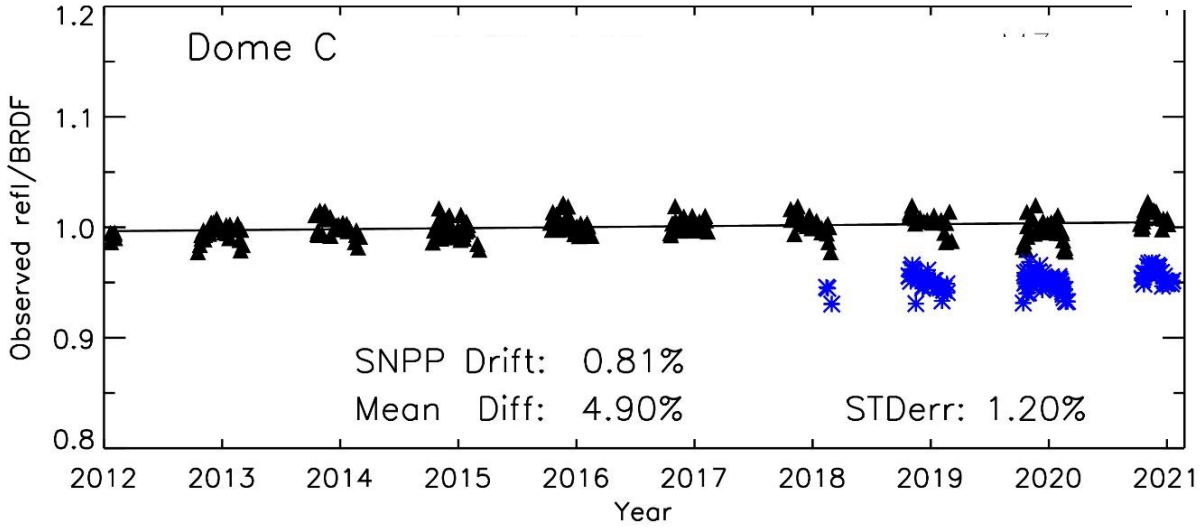
	VIS/NIR (µm)									
Method	**B1 0.65**	**B2 0.86**	**B3 0.47**	**B4 0.55**	**B8 0.41**	**B9 0.44**	**B10 0.49**	**B12 0.55**	**B13 0.67**	**B15 0.75**
SNO	**-1.2 (1.3)**	**-0.8 (1.4)**	**2.3 (4.2)**	**-0.8 (1.1)**	**0.5 (1.6)**	**1.0 (1.7)**	**-0.2 (2.2)**	**-1.5 (3.2)**	**-1.2 (3.1)**	**-2.9 (5.3)**
Desert	**-1.1 (1.0)**	**0.5 (1.1)**	**0.9 (1.7)**	**-0.3 (1.2)**	**-0.1 (1.9)**	**-0.4 (1.7)**	**n/a**	**n/a**	**n/a**	**n/a**
Dome C	**-0.8 (2.6)**	**0.6 (2.6)**	**0.8 (1.7)**	**-0.1 (2.7)**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
DCC	**0.2 (1.5)**	**n/a**	**1.8 (1.7)**	**0.8 (1.5)**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Moon	**-0.35**	**-0.41**	**0.53**	**0.14**	**-1.03**	**-1.21**	**-0.65**	**-0.12**	**-1.11**	**-1.47**

Numbers in brackets are standard errors, no SWIR bands due to xtalk (large in Terra)
No RSR correction between Terra and Aqua

SNPP and NOAA-20 RSB consistency







NOAA-20 reflectances are lower than SNPP by 2-4% for most bands. Additional larger differences for M1 and M2. Results shown here are before RSR correction

SNPP and NOAA20 RSB consistency

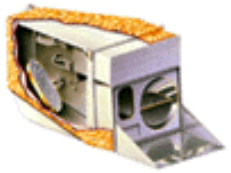
SNPP and NOAA20 VIIRS RSB comparison (SNPP – N20) (%)

	VIS/NIR (µm)								SWIR (µm)		
Method	**M1 0.41**	**M2 0.45**	**M3 0.49**	**M4 0.56**	**M5 0.67**	**M7 0.87**	**I1 0.64**	**I2 0.87**	**M8 1.24**	**M10 1.61**	**I3 1.61**
SNO	**6.2 (1.7)**	**5.9 (1.6)**	**4.9 (1.9)**	**5.0 (1.6)**	**4.7 (2.3)**	**2.9 (1.8)**	**3.1 (1.6)**	**2.8 (1.8)**	**2.7 (1.4)**	**2.6 (3.1)**	**3.7 (3.2)**
Desert	**7.1 (1.0)**	**6.1 (1.1)**	**4.3 (1.2)**	**3.5 (1.0)**	**4.8 (0.7)**	**2.7 (0.8)**	**3.5 (0.9)**	**2.9 (0.8)**	**2.3 (1.2)**	**1.9 (0.8)**	**3.1 (0.8)**
Dome C	**6.9 (1.1)**	**6.1 (1.1)**	**4.5 (1.2)**	**4.3 (3.0)**	**4.5 (2.0)**	**1.7 (2.5)**	**3.0 (2.8)**	**2.1 (2.6)**	**2.6 (8.9)**	**n/a**	**n/a**
DCC	**5.5 (0.5)**	**4.6 (0.6)**	**5.0 (0.6)**	**6.0 (0.7)**	**4.6 (0.6)**	**4.4 (0.3)**	**4.6 (0.6)**	**5.4 (0.4)**	**1.8 (0.5)**	**0.2 (1.3)**	**2.5 (1.1)**
Moon	**3.7**	**4.5**	**2.6**	**3.0**	**3.3**	**1.7**	**1.4**	**1.6**	**3.8**	**2.1**	**2.8**

Numbers in brackets are standard errors

RSR correction applied between SNPP and N20

Aqua and NOAA20 RSB consistency



Aqua and NOAA20 RSB comparison (Aqua – N20) (%)

	VIS/NIR (µm)							SWIR (µm)		
Method	**B8/M1 0.65**	**B9/M2 0.86**	**B4/M4 0.55**	**B1/M5 0.65**	**B2/M7 0.41**	**B1/I1 0.65**	**B2/I2 0.86**	**B5/M8 0.55**	**B6/M10 0.67**	**B6/I3 0.75**
SNO	**2.1 (1.5)**	**4.9 (1.4)**	**3.2 (1.5)**	**5.1 (1.5)**	**2.8 (1.7)**	**3.0 (1.5)**	**2.7 (1.7)**	**-0.5 (0.9)**	**1.2 (2.0)**	**1.8 (1.9)**
Desert	**4.4 (1.0)**	**5.5 (0.8)**	**2.4 (0.8)**	**4.3 (0.7)**	**0.7 (0.6)**	**3.6 (0.7)**	**0.9 (0.8)**	**2.9 (0.9)**	**-1.4 (0.7)**	**-0.1 (0.7)**
Dome C	**3.9 (0.9)**	**5.1 (0.7)**	**1.8 (2.5)**	**3.7 (1.8)**	**0.6 (1.8)**	**2.2 (2.1)**	**1.0 (1.9)**	**n/a**	**n/a**	**n/a**
DCC	**n/a**	**n/a**	**2.9 (1.5)**	**2.6 (1.5)**	**n/a**	**5.4 (1.6)**	**n/a**	**-1.4 (0.9)**	**0.4 (2.6)**	**1.9 (2.6)**

Numbers in brackets are standard errors

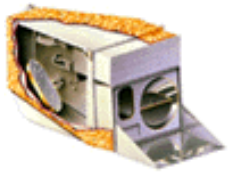
RSR correction applied between Aqua and N20

Summary

- Assessment of the calibration consistency between MODIS and VIIRS RSB is based on various vicarious approaches (SNO, desert, Dome C and DCC)
- Terra and Aqua differences are within 2% for all RSB. There is a high uncertainty of 2 to 4% for the SWIR band comparison.
- SNPP and NOAA-20 comparison shows that the NOAA-20 reflectances are systematically lower than SNPP by 2-4% and the shortest wavelength bands M1 to M3 show larger biases by about 4 to 6%.
- NOAA-20 is lower than Aqua by about 2-4 % for VIS/NIR bands and the agreement is within 2% for SWIR bands.
- Results indicate that agreement among the four approaches are up to 2.0%, indicating there are still errors that need to be considered.

Backup slides

SNPP and NOAA20 VIIRS RSB consistency

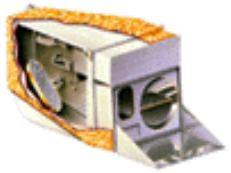


SNPP and NOAA20 VIIRS RSB comparison (SNPP – N20) (%)

	VIS/NIR (µm)								SWIR (µm)		
Method	**M1 0.41**	**M2 0.45**	**M3 0.49**	**M4 0.56**	**M5 0.67**	**M7 0.87**	**I1 0.64**	**I2 0.87**	**M8 1.24**	**M10 1.61**	**I3 1.61**
SNO	**4.9 (1.7)**	**4.8 (1.6)**	**5.5 (1.9)**	**5.8 (1.6)**	**4.3 (2.3)**	**4.2 (1.8)**	**3.8 (1.6)**	**4.6 (1.8)**	**2.8 (1.4)**	**2.5 (3.1)**	**3.7 (3.2)**
Desert	**7.0 (1.0)**	**5.1 (1.1)**	**4.7 (1.2)**	**1.6 (1.0)**	**4.8 (0.7)**	**3.2 (0.8)**	**3.4 (0.9)**	**3.7 (0.8)**	**2.2 (1.2)**	**1.9 (0.8)**	**3.4 (0.8)**
Dome C	**5.8 (1.1)**	**5.2 (1.1)**	**4.9 (1.2)**	**5.8 (3.0)**	**4.4 (2.0)**	**4.5 (2.5)**	**4.0 (2.8)**	**4.8 (2.6)**	**3.3 (8.9)**	**n/a**	**n/a**
DCC	**5.6 (0.5)**	**4.8 (0.6)**	**5.1 (0.6)**	**5.7 (0.7)**	**4.7 (0.6)**	**3.9 (0.3)**	**4.8 (0.6)**	**4.9 (0.4)**	**1.8 (0.5)**	**1.1 (1.3)**	**3.2 (1.1)**

No RSR correction between SNPP and N20

Aqua and NOAA20 RSB consistency

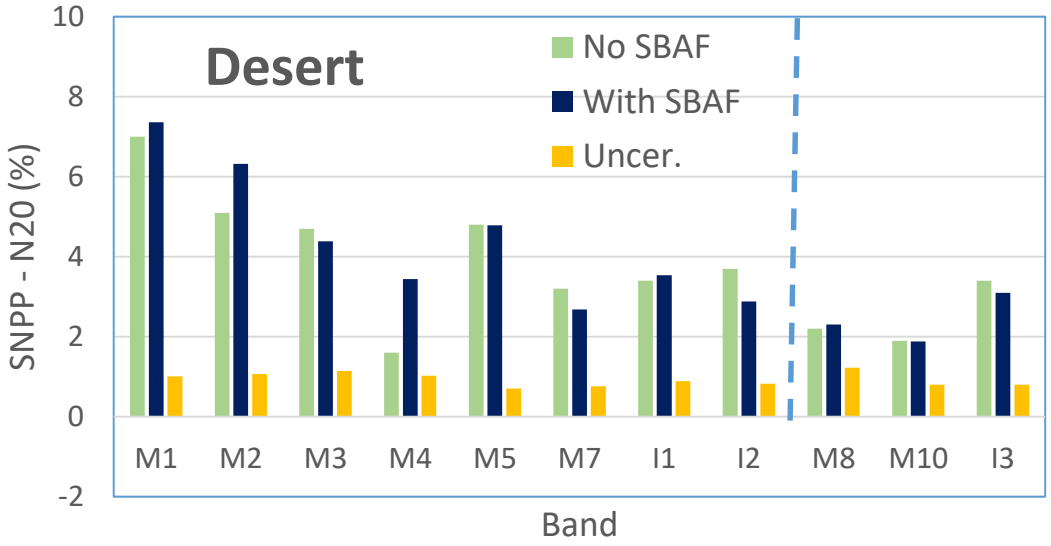


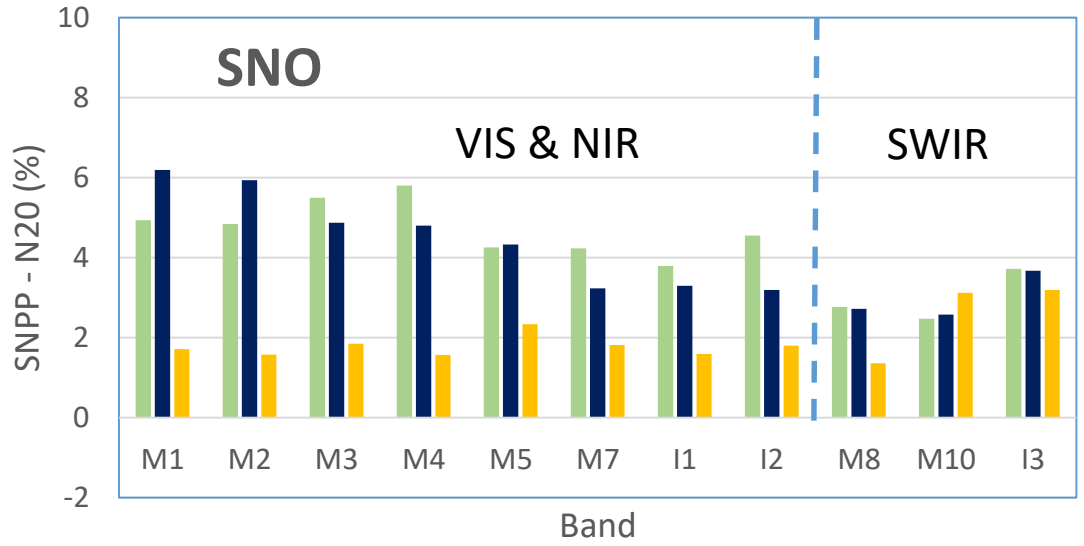
Aqua and NOAA20 RSB comparison (Aqua – N20) (%)

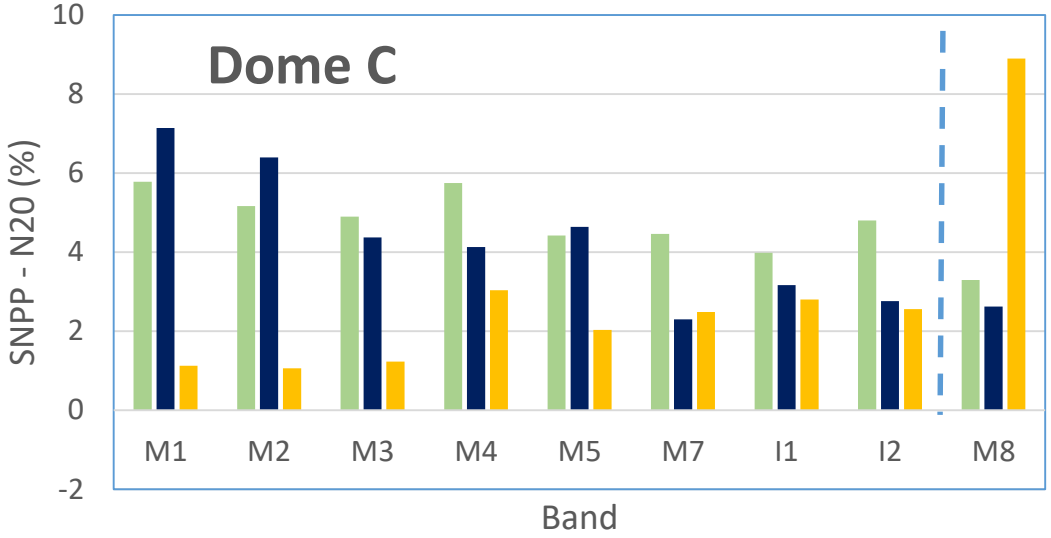
	VIS/NIR (µm)							SWIR (µm)		
Method	**B8/M1 0.65**	**B9/M2 0.86**	**B4/M4 0.55**	**B1/M5 0.65**	**B2/M7 0.41**	**B1/I1 0.65**	**B2/I2 0.86**	**B5/M8 0.55**	**B6/M10 0.67**	**B6/I3 0.75**
SNO	**2.0 (1.5)**	**3.7 (1.4)**	**3.4 (1.5)**	**-1.2 (1.5)**	**2.6 (1.7)**	**3.5 (1.5)**	**2.8 (1.7)**	**-1.3 (0.9)**	**5.7 (2.0)**	**6.5 (1.9)**
Desert	**4.3 (1.0)**	**3.8 (0.8)**	**1.1 (0.8)**	**-4.3 (0.7)**	**-0.5 (0.6)**	**4.1 (0.7)**	**-0.1 (0.8)**	**2.5 (0.9)**	**2.2 (0.7)**	**3.7 (0.7)**
Dome C	**4.0 (0.9)**	**3.5 (0.7)**	**2.3 (2.5)**	**-1.2 (1.8)**	**2.3 (1.8)**	**3.0 (2.1)**	**2.5 (1.9)**	**n/a**	**n/a**	**n/a**
DCC	**n/a**	**n/a**	**3.1 (1.5)**	**1.2 (1.5)**	**n/a**	**5.7 (1.6)**	**n/a**	**-1.6 (0.9)**	**10.4 (2.6)**	**12.2 (2.6)**

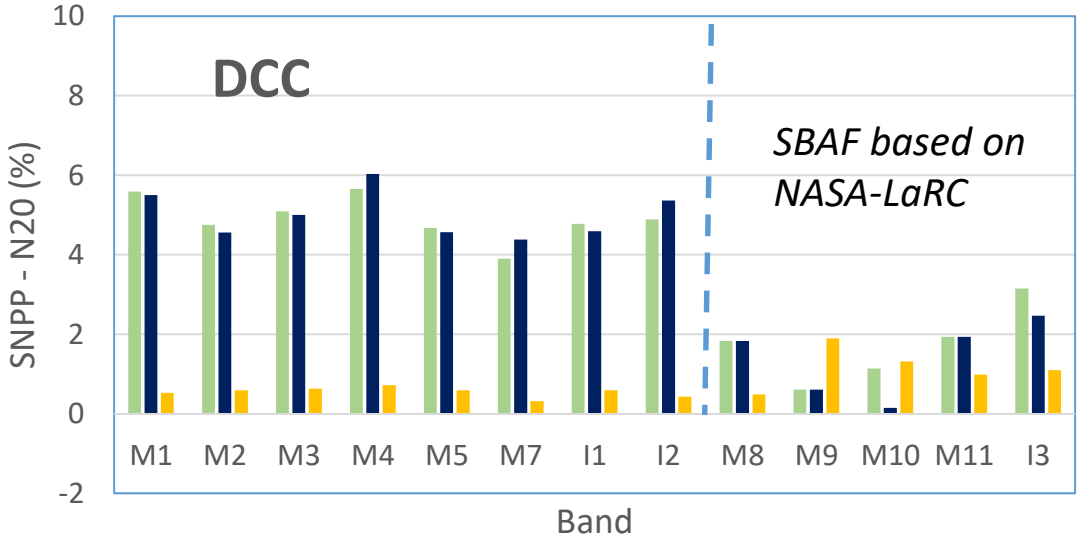
No RSR correction between Aqua and N20

SNPP and NOAA-20 VIIRS RSB consistency



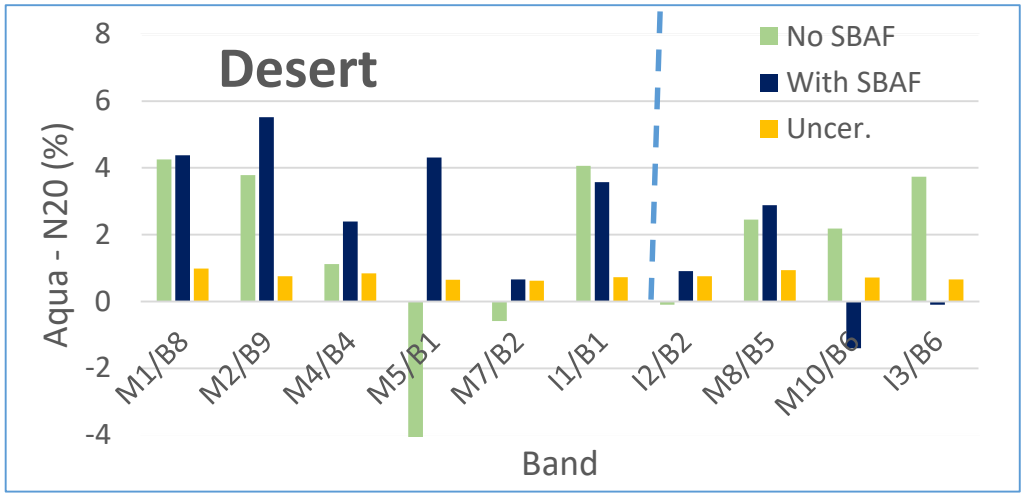


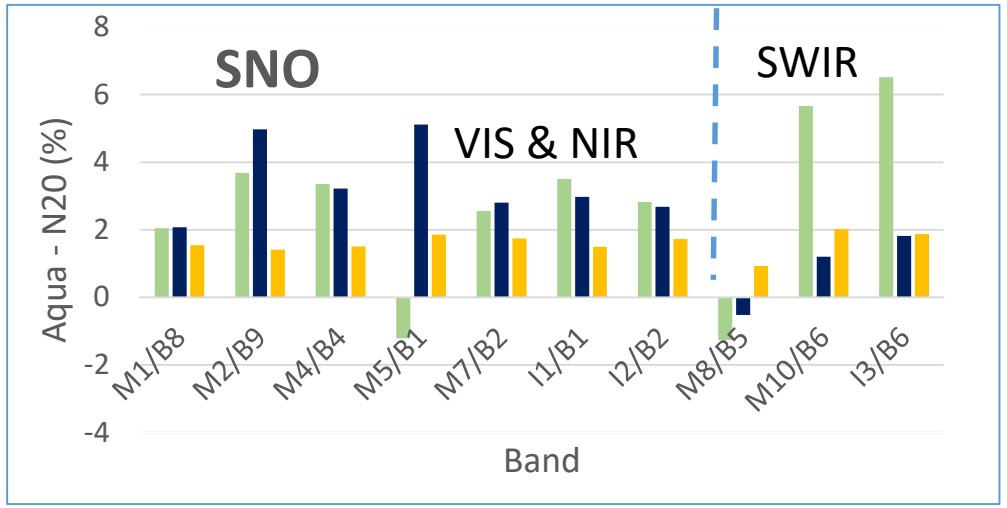


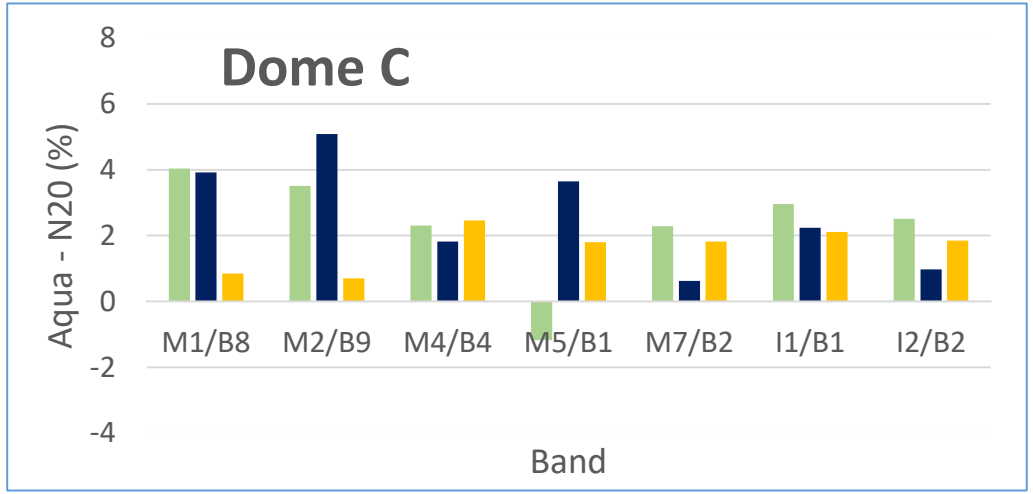


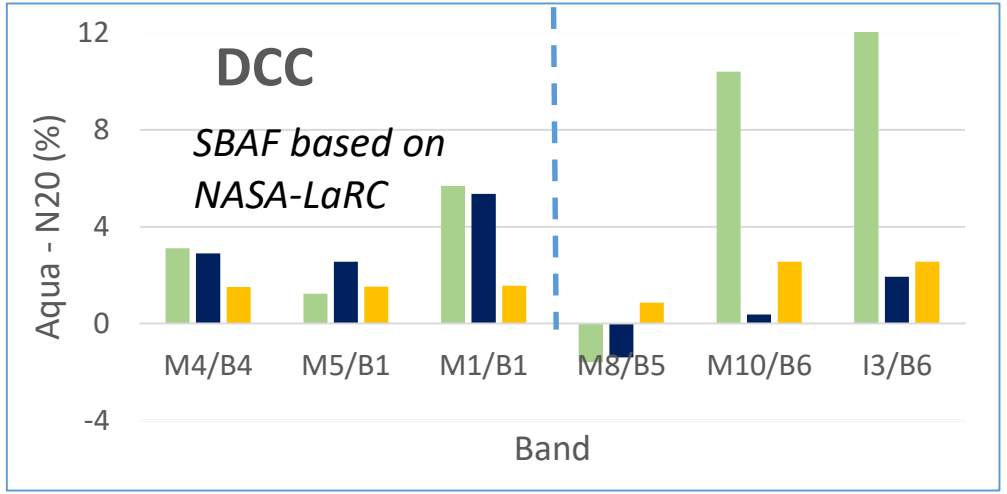
Spectral band adjustment factor (SBAF) between N20 and SNPP

Aqua MODIS and N20 VIIRS RSB consistency









Spectral band adjustment factor (SBAF) between Aqua and N20