



International
Ocean Colour Science
Meeting 2025

Advancing Global Ocean Colour Observations

On-Orbit System Vicarious Calibration for Three VIIRS Sensors

Menghua Wang

NOAA/NESDIS Center for Satellite Applications and Research (STAR)
E/RA3, 5830 University Research Ct.
College Park, MD 20740, USA

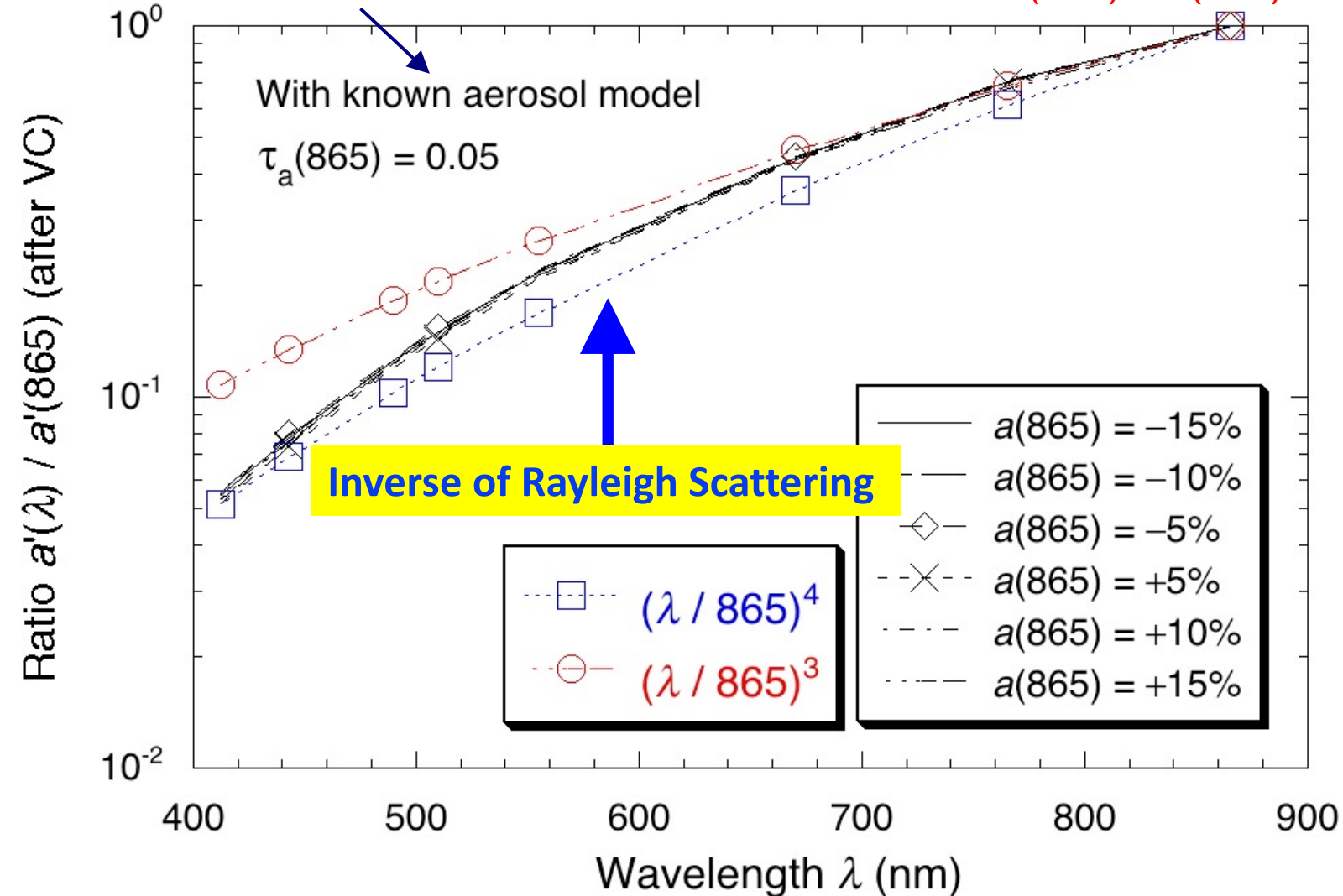
The 6th International Ocean Color Science Meeting, Darmstadt, Germany, December 1-4, 2025



System Vicarious Calibration (SVC)

Used correct aerosol model

$$a'(865) = a(865)$$



For ocean color remote sensing, post-launch vicarious calibration is necessary for visible bands.

SVC: calibration of entire system, i.e., **sensor + algorithms**

- Account for (by direct measurement or prediction) all the components of the TOA radiance and
- Compare the computed results with the sensor-measured radiance

$$L_t^{(\text{Measured})}(\lambda) = [1 + a(\lambda)] L_t^{(\text{True})}(\lambda)$$

$$L_t^{(\text{Computed})}(\lambda) = [1 + a'(\lambda)] L_t^{(\text{True})}(\lambda)$$

where $a(\lambda)$ and $a'(\lambda)$ are calibration error before and after SVC.

It is really a relative *spectral* vicarious calibration approach!



The SVC Approach for Three VIIRS Sensors



We have recently carried out the SVC for three VIIRS sensors using the same approach outlined below:

Assumption: The VIIRS NIR M7 (~862 nm) band on-orbit calibration is accurate, i.e., gain = 1 and done at **MOBY** site.

1. Generation of the VIIRS and MOBY in situ matchup data list.
2. Derivation of the VIIRS SWIR M8 SVC gain: Using fixed two aerosol models, to iteratively get M7 gain of 1.
3. Derivation of VIIRS NIR and SWIR M10 SVC gains: Using the SWIR bands M8 and M10, the SWIR-based OC data processing has been carried out iteratively, i.e., using the derived M8 SVC gain from the step 2 and adjusting M10 gain, to iteratively derive M6 gain (forcing the NIR M7 gain of 1).
4. Derivation of the VIIRS SWIR M11 SVC gain: Using the SWIR bands M8 and M11, the SWIR-based atmospheric correction has been carried out iteratively to derive the NIR M7 gain of 1.0.
5. Derivation of the VIIRS visible SVC gain set using the NIR OC data processing: Using the two NIR bands M6 and M7, the MSL12 NIR-based OC data processing has been performed using the derived NIR gains from the step 2 to directly obtain the VIIRS gains for spectral bands M1–M4, I1, and M5.
6. Derivation of the SVC gain set using the SWIR M10 and M11-based data processing: For evaluation and verification, VIIRS SVC gains are also directly derived using the SWIR M10 and M11-based OC data processing (noted as SWIR23) with the derived M10 and M11 gains (e.g., 0.8779 and 0.8434 for NOAA-21) from the steps 3 and 4.

SVC gain results for the NIR-, SWIR12-, SWIR13-, and SWIR23-based ocean color data processing using the Multi-Sensor Level-1 to Level-2 (MSL12) for VIIRS over MOBY Site

Reminder for VIIRS-SNPP:

NIR (M6 & M7) uses **745** and **862** nm bands

SWIR12 (M8 & M10) uses **1238** and **1601** nm bands

SWIR13 (M8 & M11) uses **1238** and **2257** nm bands

SWIR23 (M10 & M11) uses **1601** and **2257** nm bands



The SVC gain sets for the NIR, SWIR12, SWIR13, and SWIR23 OC data processing (VIIRS-SNPP)

NIR: 745 & 862 nm
 SWIR12: 1238 & 1601 nm
 SWIR13: 1238 & 2257 nm
 SWIR23: 1601 & 2257 nm

VIIRS-SNPP Spectral Band (nm)	VIIRS NIR- and SWIR-Based SVC Gains							
	NIR-derived $g^{(NIR)}(\lambda)$ and STD		SWIR12-derived $g^{(SWIR12)}(\lambda)$ and STD		SWIR13-derived $g^{(SWIR13)}(\lambda)$ and STD		SWIR23-derived $g^{(SWIR23)}(\lambda)$ and STD	
410 (M1)	0.9752	0.0160	0.9755	0.0206	0.9755	0.0205	0.9769	0.0228
443 (M2)	0.9732	0.0152	0.9734	0.0214	0.9735	0.0214	0.9751	0.0251
486 (M3)	0.9772	0.0141	0.9775	0.0222	0.9773	0.0225	0.9795	0.0284
551 (M4)	0.9685	0.0106	0.9688	0.0243	0.9684	0.0254	0.9714	0.0366
638 (I1)	1.0100	0.0117	1.0102	0.0279	1.0096	0.0304	1.0131	0.0491
671 (M5)	0.9740	0.0059	0.9737	0.0285	0.9733	0.0312	0.9767	0.0510
745 (M6)	0.9765	—	0.9765	0.0318	0.9758	0.0333	0.9788	0.0580
862 (M7)	1.0000	—	1.0000	0.0315	1.0000	0.0339	1.0007	0.0620
1238 (M8)	—	—	1.0050	—	1.0050	—	1.0034	0.0435
1601 (M10)	—	—	0.9960	—	—	—	0.9960	—
2257 (M11)	—	—	—	—	1.0230	—	1.0230	—

↑
 STD values *increase* with decrease of wavelengths

↑
 STD values *decrease* with decrease of wavelengths

↑
 STD values *decrease* with decrease of wavelengths

↑
 STD values *decrease* with decrease of wavelengths

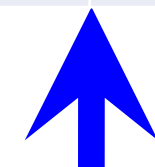


Differences (%) between the SWIR- and unified SVC gain sets (VIIRS-SNPP)

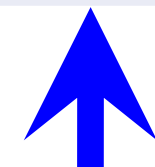
Diff12: SWIR12 vs. NIR
Diff13: SWIR13 vs. NIR
Diff23: SWIR23 vs. NIR

NIR: 745 & 862 nm
SWIR12: 1238 & 1601 nm
SWIR13: 1238 & 2257 nm
SWIR23: 1601 & 2257 nm

VIIRS-SNPP Spectral Band (nm)	$g^{(SVC)}(\lambda)$ and Differences Between SWIR- and NIR-Based SVC Gains			
	Unified SVC $g^{(SVC)}(\lambda)$	Diff12 (%) (SWIR12 vs. NIR)	Diff13 (%) (SWIR13 vs. NIR)	Diff23 (%) (SWIR23 vs. NIR)
410 (M1)	0.9752	0.031	0.031	0.174
443 (M2)	0.9732	0.021	0.031	0.195
486 (M3)	0.9772	0.031	0.010	0.235
551 (M4)	0.9685	0.031	-0.010	0.299
638 (I1)	1.0100	0.020	-0.040	0.307
671 (M5)	0.9740	-0.031	-0.072	0.277
745 (M6)	0.9765	0.000	-0.072	0.236
862 (M7)	1.0000	0.000	0.000	0.070
1238 (M8)	1.0050	—	—	-0.159
1601 (M10)	0.9960	—	—	—
2257 (M11)	1.0230	—	—	—



Gain differences between the NIR and SWIR12/SWIR13 methods are mostly within ~0.05%!



Gain differences between the NIR and SWIR23 method are significantly high mostly within ~0.25%!



VIIRS-NOAA-20 (2017-2024)

The SVC gain sets for the NIR, SWIR12, SWIR13, and SWIR23 OC data processing (VIIRS-NOAA-20)

NIR: 746 & 868 nm
SWIR12: 1238 & 1604 nm
SWIR13: 1238 & 2258 nm
SWIR23: 1604 & 2258 nm

VIIRS-NOAA-20 Spectral Band (nm)	VIIRS SWIR- and NIR-Based SVC Gains							
	NIR-derived $g^{(NIR)}(\lambda)$ and STD		SWIR12-derived $g^{(SWIR12)}(\lambda)$ and STD		SWIR13-derived $g^{(SWIR13)}(\lambda)$ and STD		SWIR23-derived $g^{(SWIR23)}(\lambda)$ and STD	
411 (M1)	1.0044	0.0174	1.0042	0.0211	1.0046	0.0208	1.0055	0.0220
445 (M2)	1.0098	0.0152	1.0097	0.0204	1.0100	0.0204	1.0112	0.0237
489 (M3)	1.0051	0.0150	1.0049	0.0224	1.0051	0.0224	1.0067	0.0285
556 (M4)	1.0073	0.0110	1.0074	0.0270	1.0074	0.0263	1.0095	0.0382
642 (I1)	1.0301	0.0062	1.0305	0.0314	1.0302	0.0310	1.0323	0.0512
667 (M5)	1.0136	0.0054	1.0134	0.0318	1.0132	0.0307	1.0153	0.0528
746 (M6)	1.0052	—	1.0052	0.0329	1.0045	0.0328	1.0060	0.0606
868 (M7)	1.0000	—	1.0001	0.0331	1.0000	0.0355	0.9993	0.0662
1238 (M8)	—	—	1.0435	—	1.0435	—	1.0395	0.0488
1604 (M10)	—	—	1.0235	—	—	—	1.0235	—
2258 (M11)	—	—	—	—	1.0330	—	1.0330	—

Differences (%) between the SWIR- and unified/NIR SVC gain sets (VIIRS-NOAA-20)

Diff12: SWIR12 vs. NIR
Diff13: SWIR13 vs. NIR
Diff23: SWIR23 vs. NIR

VIIRS-NOAA-20 Spectral Band (nm)	$g^{(SVC)}(\lambda)$ and Differences Between SWIR- and NIR-Based SVC Gains			
	Unified SVC $g^{(SVC)}(\lambda)$	Diff12 (%) (SWIR12 vs. NIR)	Diff13 (%) (SWIR13 vs. NIR)	Diff23 (%) (SWIR23 vs. NIR)
411 (M1)	1.0044	-0.020	0.020	0.110
445 (M2)	1.0098	-0.010	0.020	0.139
489 (M3)	1.0051	-0.020	0.000	0.159
556 (M4)	1.0073	0.010	0.010	0.218
642 (I1)	1.0301	0.039	0.010	0.214
667 (M5)	1.0136	-0.020	-0.039	0.168
746 (M6)	1.0052	0.000	-0.070	0.080
868 (M7)	1.0000	0.010	0.000	-0.070
1238 (M8)	1.0435	—	—	-0.383
1604 (M10)	1.0235	—	—	—
2258 (M11)	1.0330	—	—	—



The SVC gain sets for the NIR, SWIR12, SWIR13, and SWIR23 OC data processing (VIIRS-NOAA-21)

NIR: 747 & 868 nm
SWIR12: 1241 & 1613 nm
SWIR13: 1241 & 2252 nm
SWIR23: 1613 & 2252 nm

VIIRS-NOAA-21 Spectral Band (nm)	VIIRS SWIR- and NIR-Based SVC Gains							
	NIR-derived $g^{(NIR)}(\lambda)$ and STD		SWIR12-derived $g^{(SWIR12)}(\lambda)$ and STD		SWIR13-derived $g^{(SWIR13)}(\lambda)$ and STD		SWIR23-derived $g^{(SWIR23)}(\lambda)$ and STD	
411 (M1)	1.0284	0.0217	1.0283	0.0222	1.0286	0.0232	1.0318	0.0292
445 (M2)	1.0317	0.0174	1.0318	0.0235	1.0320	0.0244	1.0363	0.0316
488 (M3)	1.0165	0.0151	1.0169	0.0290	1.0169	0.0294	1.0228	0.0391
555 (M4)	1.0231	0.0120	1.0236	0.0437	1.0235	0.0427	1.0327	0.0555
641 (I1)	1.0236	0.0063	1.0246	0.0603	1.0250	0.0618	1.0374	0.0771
671 (M5)	1.0137	0.0048	1.0144	0.0687	1.0140	0.0653	1.0263	0.0810
747 (M6)	1.0051	—	1.0051	0.0761	1.0055	0.0745	1.0184	0.0908
868 (M7)	1.0000	—	1.0000	0.0825	1.0000	0.0783	1.0125	0.0981
1241 (M8)	—	—	0.8982	—	0.8982	—	0.8980	0.0485
1613 (M10)	—	—	0.8779	—	—	—	0.8779	—
2252 (M11)	—	—	—	—	0.8434	—	0.8434	—

Differences (%) between the SWIR- and unified/NIR SVC gain sets (VIIRS-NOAA-21)

Diff12: SWIR12 vs. NIR
Diff13: SWIR13 vs. NIR
Diff23: SWIR23 vs. NIR

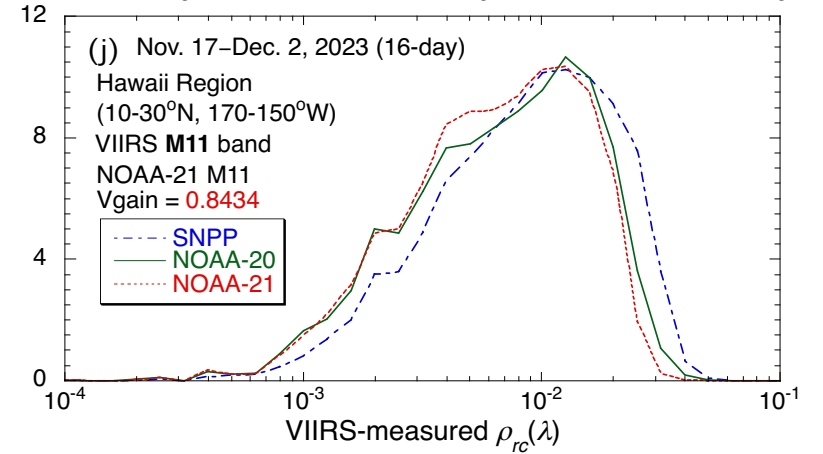
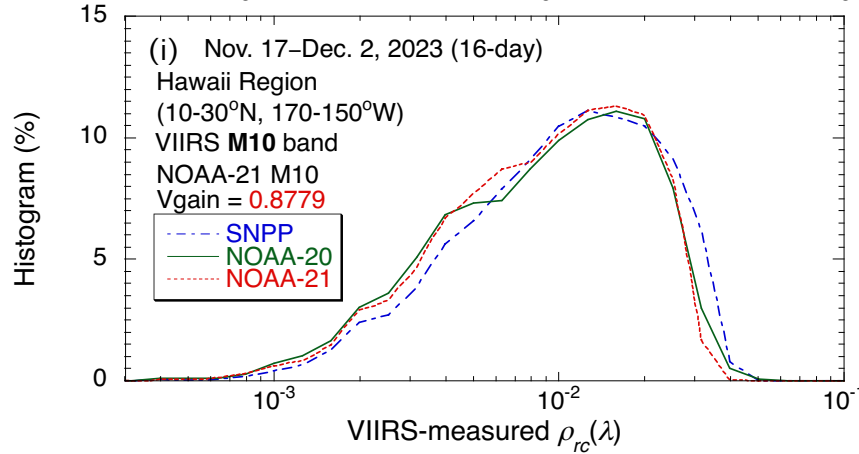
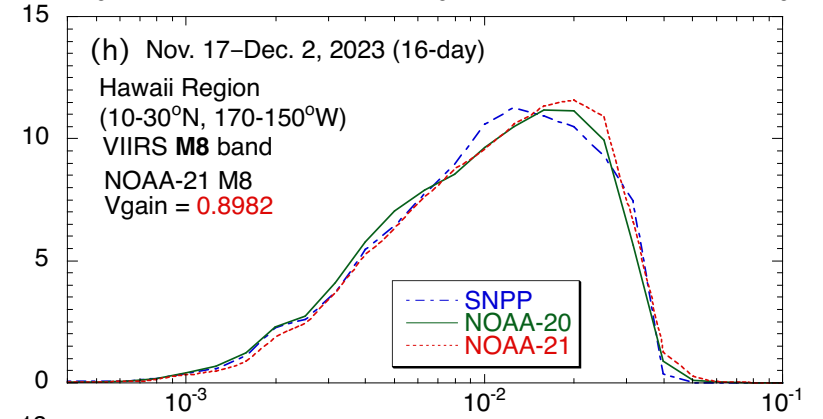
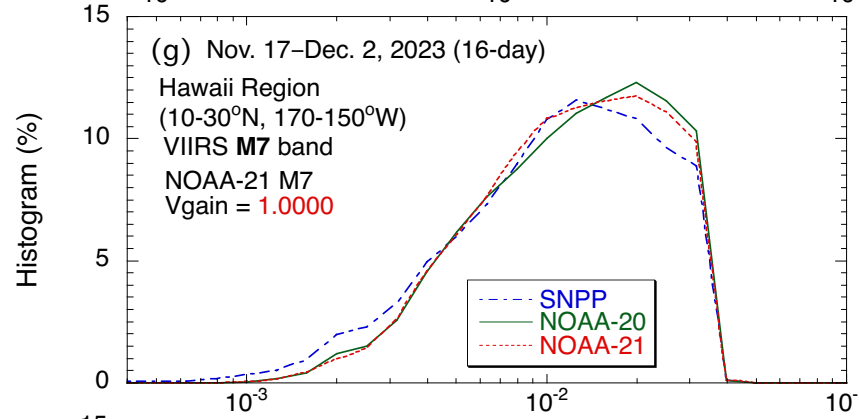
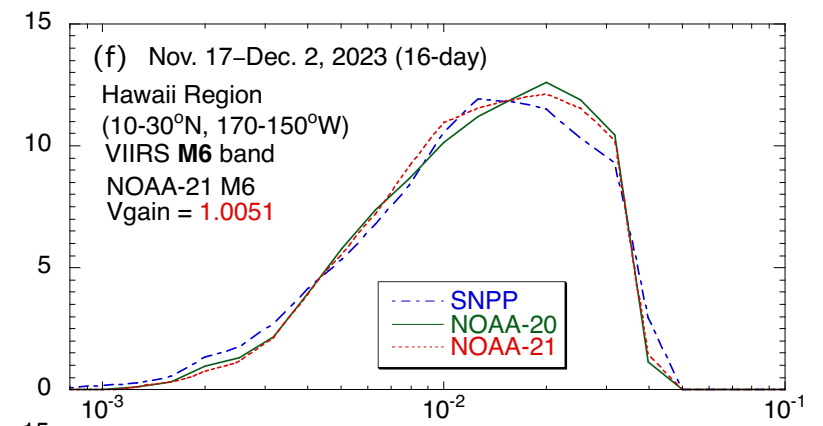
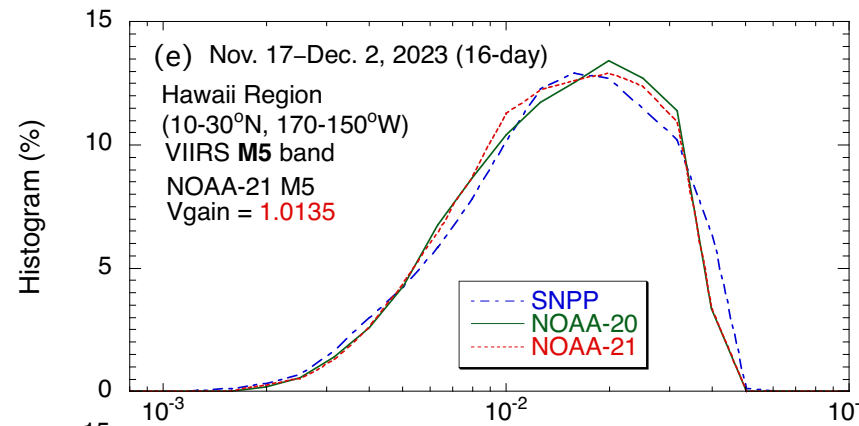
VIIRS-NOAA-21 Spectral Band (nm)	$g^{(SVC)}(\lambda)$ and Differences Between SWIR- and NIR-Based SVC Gains			
	Unified SVC $g^{(SVC)}(\lambda)$	Diff12 (%) (SWIR12 vs. NIR)	Diff13 (%) (SWIR13 vs. NIR)	Diff23 (%) (SWIR23 vs. NIR)
411 (M1)	1.0284	-0.010	0.019	0.331
445 (M2)	1.0317	0.010	0.029	0.446
488 (M3)	1.0165	0.039	0.039	0.620
555 (M4)	1.0231	0.049	0.039	0.938
641 (I1)	1.0236	0.098	0.137	1.348
671 (M5)	1.0137	0.069	0.030	1.243
747 (M6)	1.0051	0.000	0.040	1.323
868 (M7)	1.0000	0.000	0.000	1.250
1241 (M8)	0.8982	—	—	-0.022
1613 (M10)	0.8779	—	—	—
2252 (M11)	0.8434	—	—	—



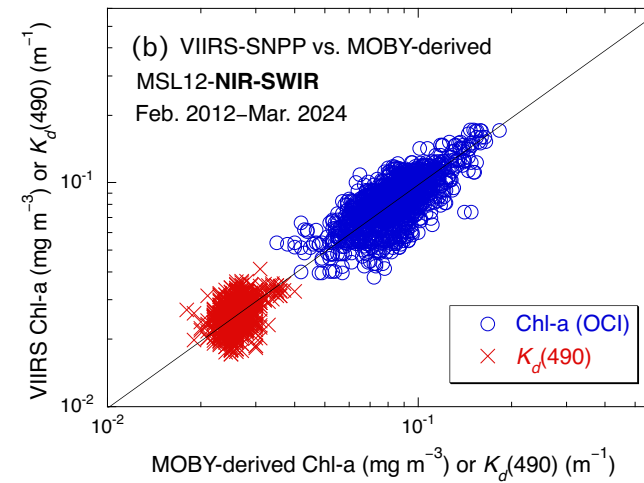
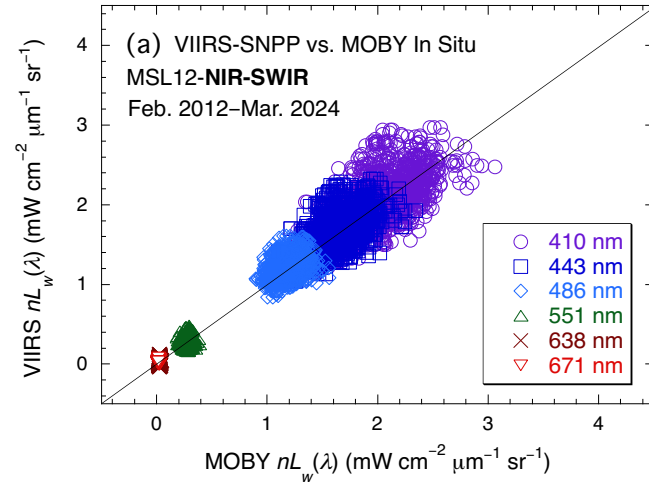
VIIRS-measured Rayleigh-corrected reflectance (16-day) over MOBY site (Nov. 17-Dec. 2, 2023)

SVC gains are applied for
three VIIRS sensors

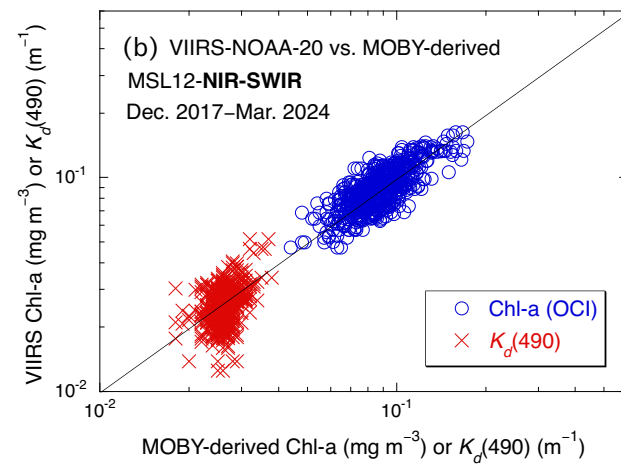
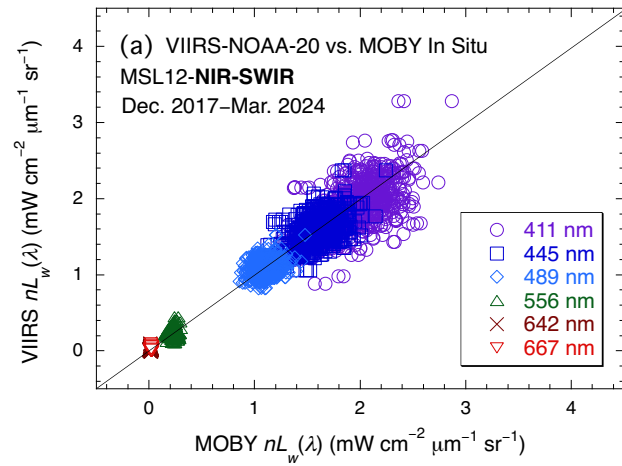
Results show that the SVC
gains are reasonable!



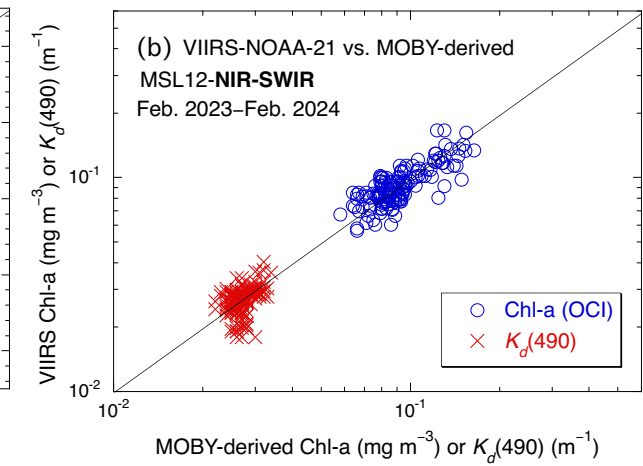
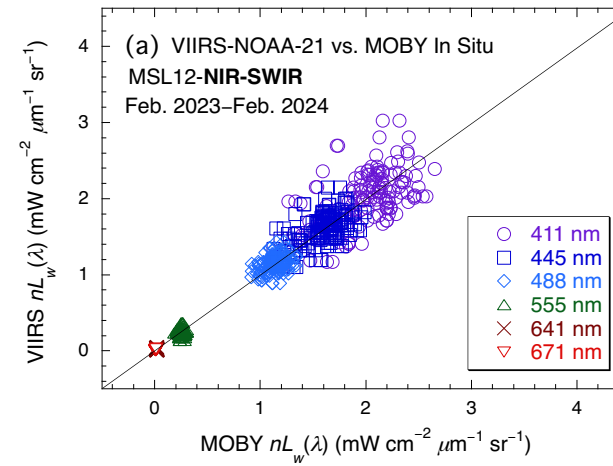
VIIRS-derived OC Products vs. MOBY-In situ-Measured or Derived Data



← VIIRS-SNPP (2012-2024)



VIIRS-NOAA-20 (2017-2024)



VIIRS-NOAA-21 (2023-2024)



Statistical Results: VIIRS-derived vs. MOBY-In situ-Measured

Product	Comparison of Ocean Color Products (VIIRS vs. In Situ) (NIR-SWIR-based approach)						
	Ratio (VIIRS/In Situ)			Difference (VIIRS–In Situ)			Num
	Mean	Median	STD	Mean	Median	STD	
$nL_w(410)$	1.0084	0.9886	0.1301	0.0085	-0.0228	0.2581	1513
$nL_w(443)$	1.0117	0.9928	0.1197	0.0130	-0.0124	0.1942	1513
$nL_w(486)$	1.0098	0.9931	0.1086	0.0070	-0.0087	0.1283	1513
$nL_w(551)$	1.0164	0.9896	0.1897	0.0026	-0.0030	0.0521	1513
$nL_w(638)$	1.0181	0.9461	0.9660	0.0006	-0.0015	0.0260	1513
$nL_w(671)$	1.2043	1.0841	0.6729	0.0033	0.0017	0.0128	1513
Chl-a	0.9982	1.0036	0.1693	-0.0010	0.0004	0.0142	1513
$K_d(490)$	0.9838	0.9700	0.1290	-0.0005	-0.0008	0.0034	1513

← VIIRS-SNPP (2012-2024)

Product	Comparison of Ocean Color Products (VIIRS vs. In Situ) (NIR-SWIR-based approach)						
	Ratio (VIIRS/In Situ)			Difference (VIIRS–In Situ)			Num
	Mean	Median	STD	Mean	Median	STD	
$nL_w(411)$	0.9737	0.9751	0.1496	-0.0633	-0.0515	0.2946	638
$nL_w(445)$	0.9921	0.9816	0.1169	-0.0198	-0.0284	0.1839	638
$nL_w(489)$	0.9933	0.9790	0.1084	-0.0127	-0.0224	0.1195	638
$nL_w(556)$	0.9911	0.9759	0.2066	-0.0039	-0.0057	0.0480	638
$nL_w(642)$	1.2864	1.1991	0.7219	0.0051	0.0041	0.0144	638
$nL_w(667)$	1.3982	1.1965	1.0125	0.0047	0.0029	0.0131	638
Chl-a	1.0167	1.0103	0.1520	0.0007	0.0009	0.0134	638
$K_d(490)$	0.9733	0.9600	0.1742	-0.0007	-0.0011	0.0046	638

Product	Comparison of Ocean Color Products (VIIRS vs. In Situ) (NIR-SWIR-based approach)						
	Ratio (VIIRS/In Situ)			Difference (VIIRS–In Situ)			Num
	Mean	Median	STD	Mean	Median	STD	
$nL_w(411)$	1.0140	0.9996	0.1709	0.0092	-0.0007	0.3197	148
$nL_w(445)$	1.0117	0.9985	0.1242	0.0095	-0.0024	0.1908	148
$nL_w(488)$	1.0072	1.0028	0.0979	0.0041	0.0031	0.1111	148
$nL_w(555)$	1.0036	1.0099	0.1867	-0.0008	0.0023	0.0466	148
$nL_w(641)$	1.2074	1.1741	0.4911	0.0037	0.0035	0.0096	120
$nL_w(671)$	1.2567	1.1096	0.6106	0.0025	0.0011	0.0064	122
Chl-a	0.9982	0.9797	0.1463	-0.0015	-0.0021	0.0148	148
$K_d(490)$	0.9895	1.0000	0.1343	-0.0003	0.0000	0.0036	148



- We have recently carried out SVC for three VIIRS sensors (SNPP, NOAA-20, and NOAA-21) over MOBY site using the same NIR-SWIR SVC approach.
- We have assumed that the VIIRS NIR M7 band has the gain of 1.0 for the three VIIRS sensors (i.e., the on-orbit radiometric calibration at M7 band is accurate for the OC SVC procedure).
- It is also assumed that on-orbit radiometric calibrations for the three VIIRS sensors are independent.
- Results show that the SVC gain sets for three VIIRS sensors are consistent and generally accurate. Particularly, the NIR- and SWIR-based SVC gain sets are highly consistent (within $\sim 0.05\%$), providing the basis for carrying out the NIR-SWIR-based global OC data processing.
- We have also provided the VIIRS-MOBY matchup results using the derived SVC gain sets for three VIIRS sensors, showing strong evidence for the effectiveness of the derived SVC gain sets.
- In addition, we have developed a method to evaluate the effectiveness of the obtained VIIRS SVC gains using the Rayleigh-corrected reflectance $\rho_{rc}(\lambda)$ over the Hawaii MOBY region for a 16-day period in the wintertime, which has provided useful information for the SVC performance.
- With the new SVC gain sets, the mission-long three VIIRS global ocean color data have been re-processed using the MSL12 NIR-SWIR-based ocean color data processing, showing significantly improved OC results.

Website:

<https://www.star.nesdis.noaa.gov/sod/mecb/color/>

