Provisional Maturity Science Review For NOAA-21 Ocean Color Algorithm

Presented by Menghua Wang

Date: 03/07/2024

JPSS/GOES-R Data Product Validation Maturity Stages - COMMON DEFINITIONS (Nominal Mission)

1. Beta

- Product is minimally validated, and may still contain significant identified and unidentified errors.
- Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.
- Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.

2. Provisional

- Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
- Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.

3. Validated

- Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).
- Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.
- Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.
- Product is ready for operational use based on documented validation findings and user feedback.
- Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.

VIIRS-NOAA-21 **Ocean Color** PROVISIONAL MATURITY REVIEW MATERIAL

Acknowledgements: This work was supported by JPSS/VIIRS funding. We thank MOBY team for in situ optics data, NASA SeaBASS and AERONET-OC in situ data, CoastWatch, and VIIRS OC Cal/Val PIs and their collaborators in support of VIIRS Cal/Val activities.

Outline

- Algorithm Cal/Val Team Members
- Product Overview/Requirements
- Evaluation of algorithm performance to specification requirements
  - Algorithm version, processing environment
  - Evaluation of the effect of required algorithm inputs
  - Quality flag analysis/validation
  - Error Budget
- User Feedback
- Downstream Product Feedback
- Risks, Actions, and Mitigations
- Documentation (Science Maturity Check List)
- Conclusion
- Path Forward

Requirement Check List – Ocean Color/Chlorophyll

DPS	Requirement
DPS-88	The Ocean Color/Chlorophyll product shall provide ocean color (normalized water-leaving radiance nLw) and chlorophyll-a concentration; for ocean, coastal, or inland water; daytime; in clear conditions; at the refresh rate of the instrument.
DPS-90	The Ocean Color/Chlorophyll product shall provide ocean color (normalized water-leaving radiance nLw) over open oceans and at blue band (443 nm) with a measurement precision of 5% (science quality data), over the measurement range of the instrument.
DPS-91	The Ocean Color/Chlorophyll product shall provide chlorophyll-a concentration over open oceans with a measurement precision of 30% (science quality data), over the measurement range of the instrument.
DPS-93	The Ocean Color/Chlorophyll product shall provide ocean color (normalized water-leaving radiance nLw) over open oceans and at blue band (443 nm) with a measurement accuracy of 5% (science quality data).
DPS-94	The Ocean Color/Chlorophyll product shall demonstrate that over open oceans errors in normalized water-leaving radiance nLw are spectrally correlated in the contributing sensor bands.
DPS-95	The Ocean Color/Chlorophyll product shall provide chlorophyll-a concentration over open oceans with a measurement accuracy of 30% (science quality data).

VIIRS Ocean Color EDR & Cal/Val Teams

EDR	Name	Organization	Funding Agency	Task
Lead	**Menghua Wang (OC EDR & Cal/Val Lead),** L. Jiang, K. Mikelsons, X. Liu, W. Shi, L. Tan, X. Wang, J. Wei, L. Qi, **M. Ondrusek,** E. Stengel, C. Kovach	NOAA/NESDIS/ STAR	JPSS/NJO	Leads – Ocean Color EDR Team & Cal/Val Team OC products, algorithms, SDR, EDR, Cal/Val, vicarious cal., refinements, data processing, reprocessing, algorithm improvements, software updates, data validations and analyses
External Teams	**Sherwin Ladner**	NRL	JPSS/NJO	Ocean color data validation, Cruise participation and support, WAVE_CIS (AERONET-OC site) operation
	Nicholas Tufillaro	OSU	JPSS/NJO	Ocean color validation, Cruise data matchup West Coast
	Matthew Ragan	USC	JPSS/NJO	Eureka (AERONET-OC Site)
	Alex Gilerson	CUNY	JPSS/NJO	LISCO (AERONET-OC site), Cruise data and matchup
	Chuanmin Hu	USF	JPSS/NJO	NOAA data continuity, OC data validation
	Ken Voss & **MOBY** team	Miami	JPSS/NJO	Marine Optical Buoy (MOBY)
	Joaquim Goes	Columbia	JPSS/NJO	Ocean color data validation and evaluation Ocean color optics matchup

Working with: **NOAA CoastWatch**, VIIRS SDR team, NOAA various line-office reps, NOAA NCEI, NOAA OCPOP, IOCCG, NASA, ESA, EUMETSAT, etc.
Collaborators: D. Antoine (BOUSSOLE), AERONET-OC (NASA-GSFC), R. Frouin (for PAR), and many others.

Multi-Sensor Level-1 to Level-2 (MSL12) Ocean Color Data Processing System

➢ Multi-Sensor Level-1 to Level-2 (**MSL12**)

- ✓ MSL12 was developed during NASA SMIBIOS project (1997-2003) for a consistent multi-sensor ocean color data processing (Wang, 1999; Wang and Franz, 2000), i.e., it is measurement-based ocean color data processing system.
- ✓ It has been used for producing ocean color products from various satellite ocean color sensors, e.g., SeaWiFS, MOS, OCTS, POLDER, MODIS, GOCI, etc.

➢ **MSL12** Ocean Color Data Processing

- ✓ NOAA-MSL12 is based on SeaDAS version 4.6.
- ✓ Some significant improvements: (1) the SWIR-based data processing, (2) Rayleigh and aerosol LUTs, (3) algorithms for detecting absorbing aerosols and turbid waters, (4) ice detection algorithm, (5) improved straylight/cloud shadow algorithm, & many others.
- ✓ In 2014, some new algorithms (New NIR reflectance correction, Destriping, K_d(PAR), etc.)

➢ **MSL12** for VIIRS Ocean Color Data Processing

- ✓ Routine ocean color data processing (daily, 8-day, monthly) since VIIRS launch.
- ✓ Coastal turbid and inland waters from other approaches, e.g., the **SWIR approach**, results in the US east coastal, China's east coastal, Lake Taihu, Lake Okeechobee, Aral Sea, etc.
- ✓ Capability for multi-sensor ocean color data processing, e.g., MODIS-Aqua, VIIRS (SNPP, NOAA-20, NOAA-21), OLCI/Stentinel-3A/3B, GOCI, and SGLI/GCOM-C data processing capability.

Processing Environment and Algorithms (1 slide)

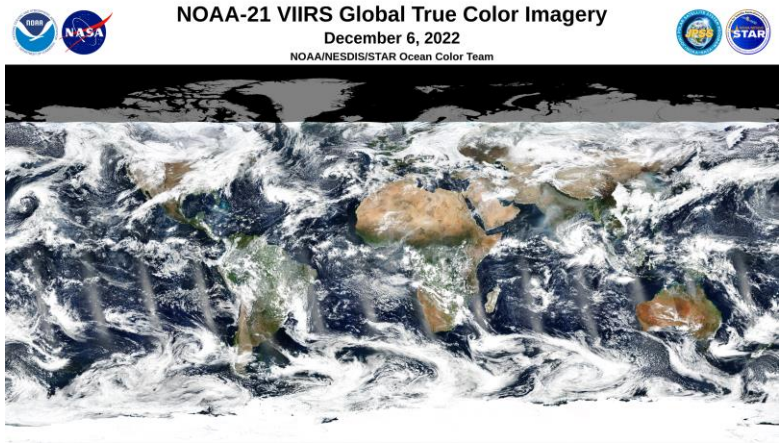
- Description of processing environment and algorithms used to achieve the maturity stage:
  - Algorithm version: MSL12 version 1.61
  - Version of LUTs used: MSL12 version 1.61 (update 1)
  - Effective date: March 1, 2024

MSL12 Level-2 Flags/Masks

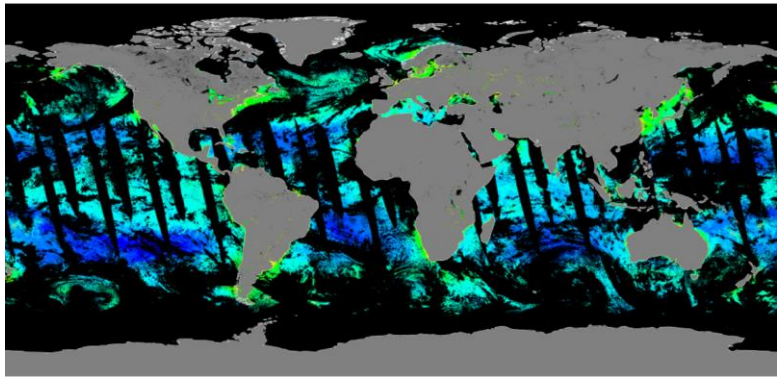
Bit	Name	Brief Description	L2 Mask Default	L3 Mask Default
00	ATMFAIL	Atmospheric correction failure		On
01	LAND	Pixel is over land	On	On
02	LOWLWCORR	Low nL_w values at the blue band/correction applied		
03	HIGLINT	Strong sun glint contamination		On
05	HITSATZEN	Sensor-zenith angle exceeds threshold		On
06	COASTZ	Pixel is over shallow water		
07	LANDADJ	Probable land-adjacent effect contamination		
09	CLOUD	Probable cloud contamination	On	On
11	TURBIDW	Turbid water detected		
12	HISOLZEN	Solar-zenith angle exceeds threshold		On
13	HITAU	High aerosol optical thickness		
14	LOWLW	Very low water-leaving radiance at green band		On
15	CHLFAIL	Chl-a algorithm failure		On
16	NAVWARN	Navigation quality is suspect		On
17	ABSAER	Absorbing aerosols detected		
18	CLDSHDSTL	Cloud straylight or shadow contamination		On
19	MAXAERITER	Maximum iterations reached for the NIR iteration		On
20	MODGLINT	Moderate sun glint contamination		
21	CHLWARN	Chl-a is out of range		On
22	ATMWARN	Atmospheric correction is suspect		
23	ALGICE	Sea ice pixel identified from $nL_w(\lambda)$ spectrum		On
24	SEAICE	Sea ice pixel identified from ancillary files		On
25	NAVFAIL	Navigation failure		On
29	FROMSWIR	Derived from the SWIR atmospheric correction		
31	NEGLRC	Negative Rayleigh-corrected radiance		

VIIR-NOAA-21 Initial Data Processing (Beta version)

- NOAA-21 satellite was successfully launched on November 10, 2022, at the 1:49 AM (PST) at the Vandenberg Space Force Base (VSFB) in California.
- VIIRS-NOAA-21 data started on December 5, 2022, and global true color image was generated on December 6, 2022.
- After getting the VIIRS-NOAA-21 SDR, we were able to immediately generating global ocean color products.
- In fact, we have been routinely generating VIIRS-NOAA-21 global ocean color products since December 5, 2022 (but VIIRS data were stopped for some periods).
- VIIRS-NOAA-21 global ocean color products have been routinely produced. Data flow has been smooth (Level-1B to Level-2 to Level-3) without any issues.
- All VIIRS-NOAA-21 global ocean color product images have been routinely generated and displayed in OCView, including Level-3 daily, 8-day, monthly, and climatology data/images.



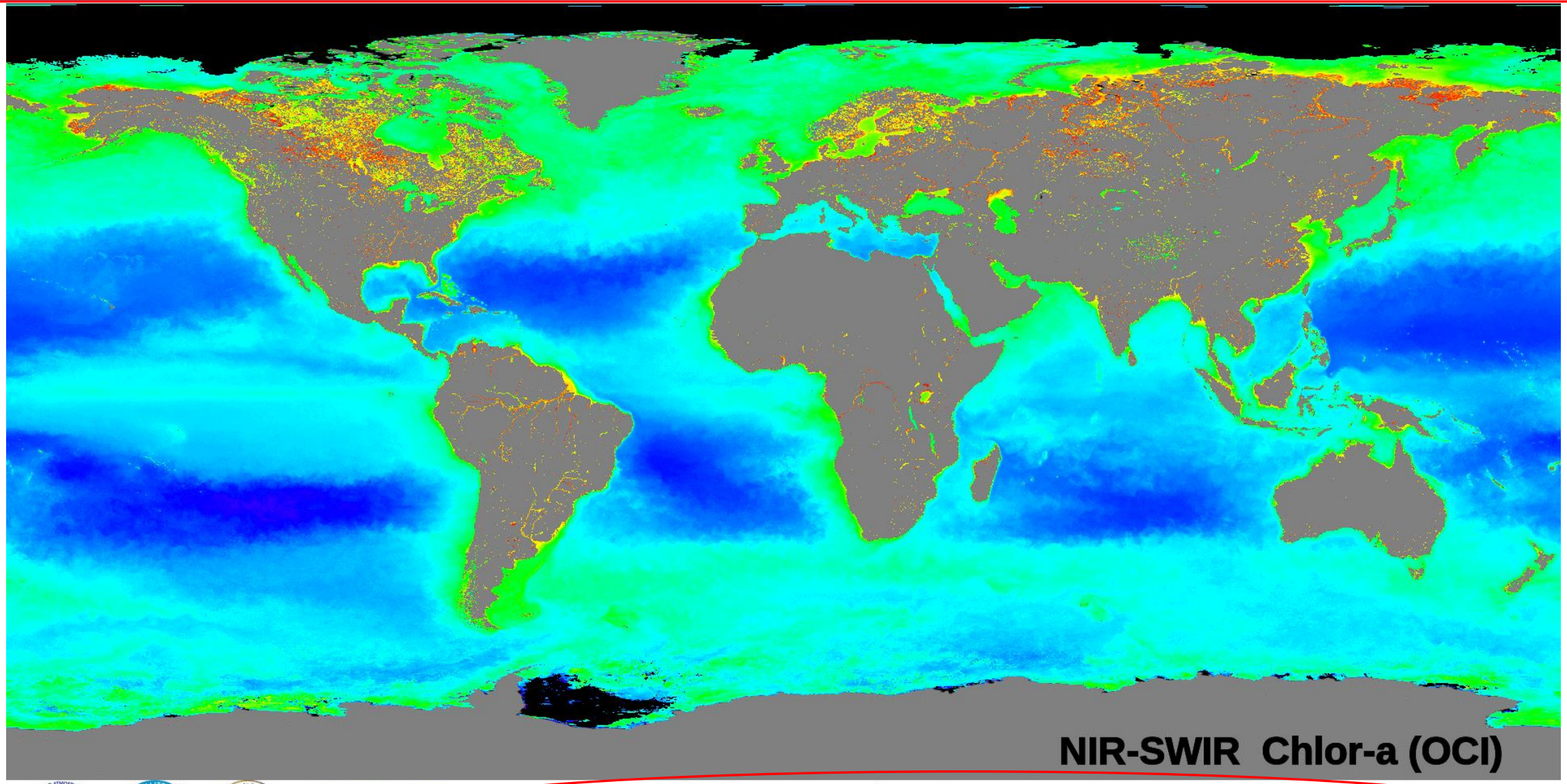
Global Chl-a from VIIRS-NOAA-21 on April 9, 2023

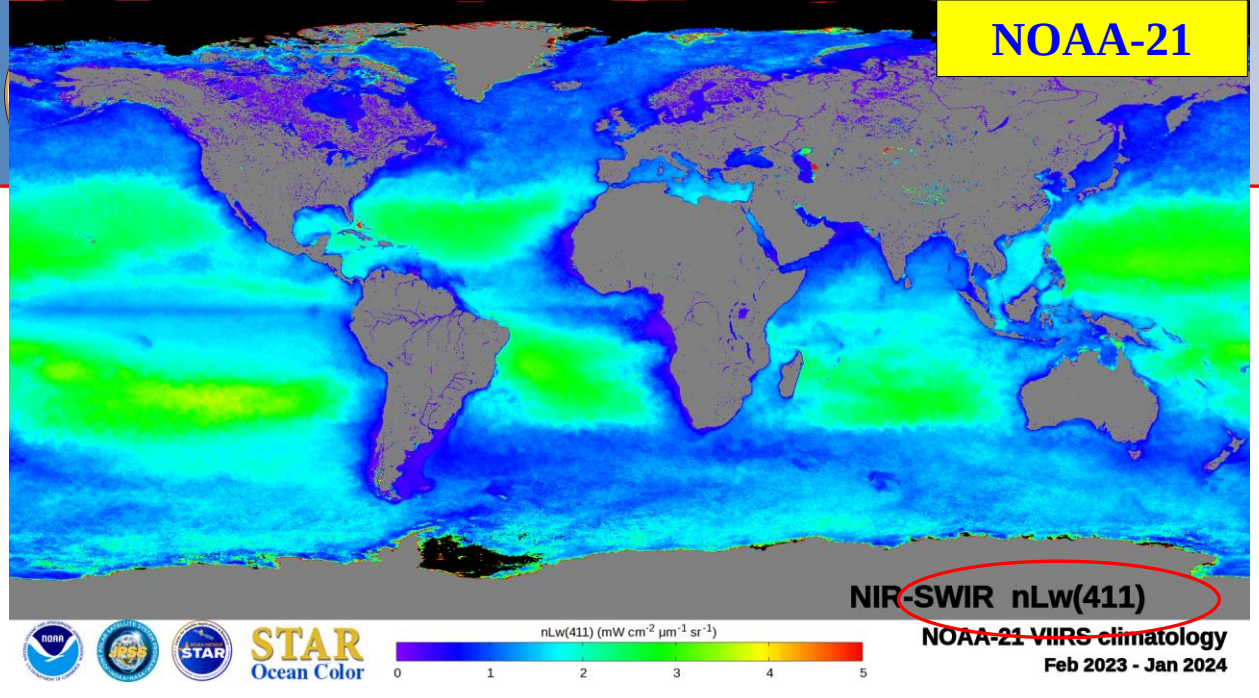


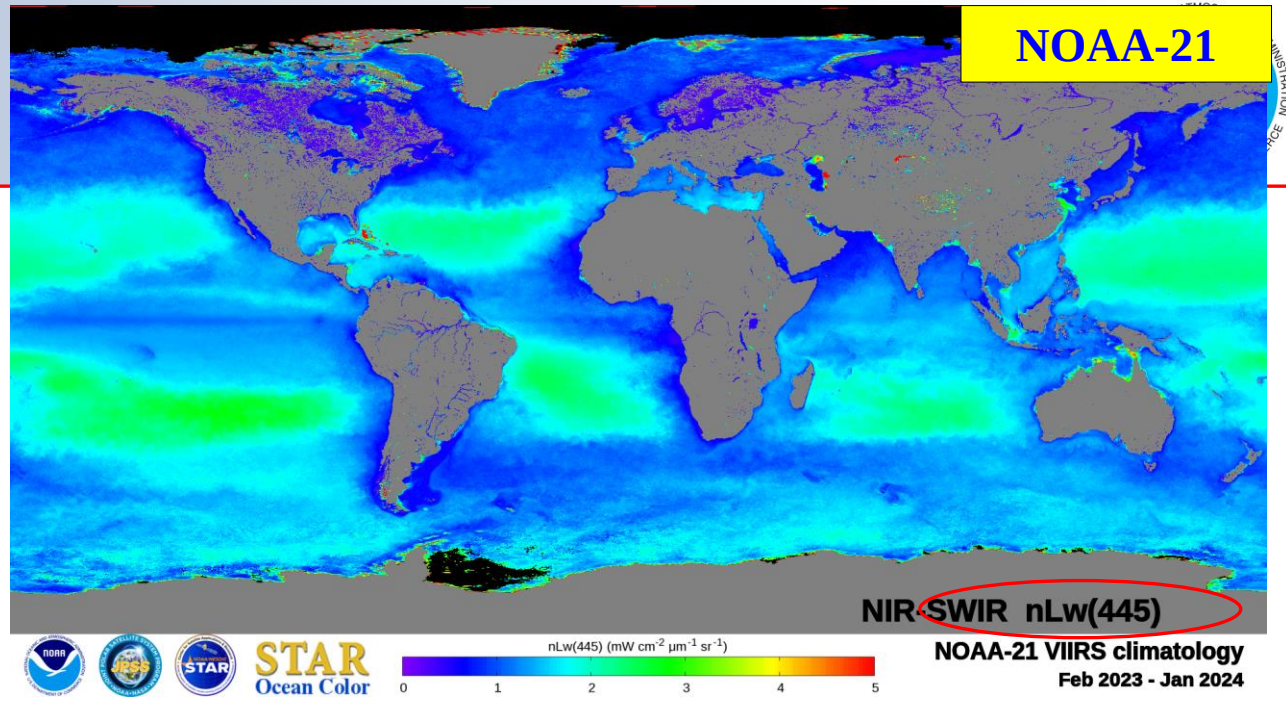
Producing VIIRS-NOAA-21 Global Ocean Color Products

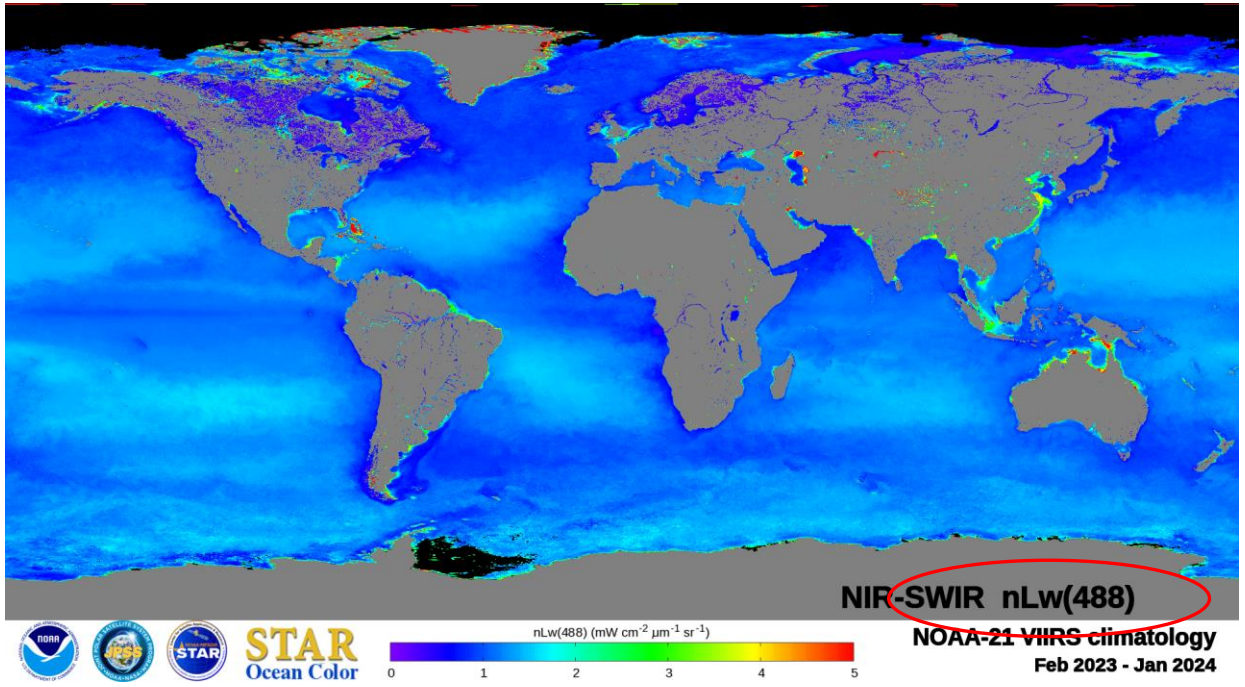
- The VIIRS Ocean Color EDR team has made very significant effort on producing accurate VIIRS-NOAA-21 ocean color products.
  - We used the MOBY in situ $nL_w(\lambda)$ spectra measurements from June 1–December 2, 2023, due to some sensor calibration issues with VIIRS SWIR bands in early months in 2023.
  - After extensive work, we derived the vicarious gains for NOAA-21: 1.0284, 1.0317, 1.0165, 1.0231, 1.0240, 1.0135, 1.0051, 1.0000, 0.8982, 0.8779, and 0.8434, corresponding to the VIIRS spectral bands of M1-M4, I1, M5-M8, and M10-M11, respectively.
  - With the new vicarious gains for NOAA-21, mission-long VIIRS-NOAA-21 ocean color data have been reprocessed (Feb 2023 to present).
- With the reprocessed mission-long NOAA-21 OC data, we have carried out detailed data evaluations using the in situ (MOBY, AERONET-OC) and satellite measurements (VIIRS-SNPP and NOAA-20) with regional and global coverage.
- VIIRS-NOAA-21 global true color and ocean color product images are being routinely produced and displayed in OCView.
- NOAA-21 OC data are being routinely monitored and evaluated using the in situ data.

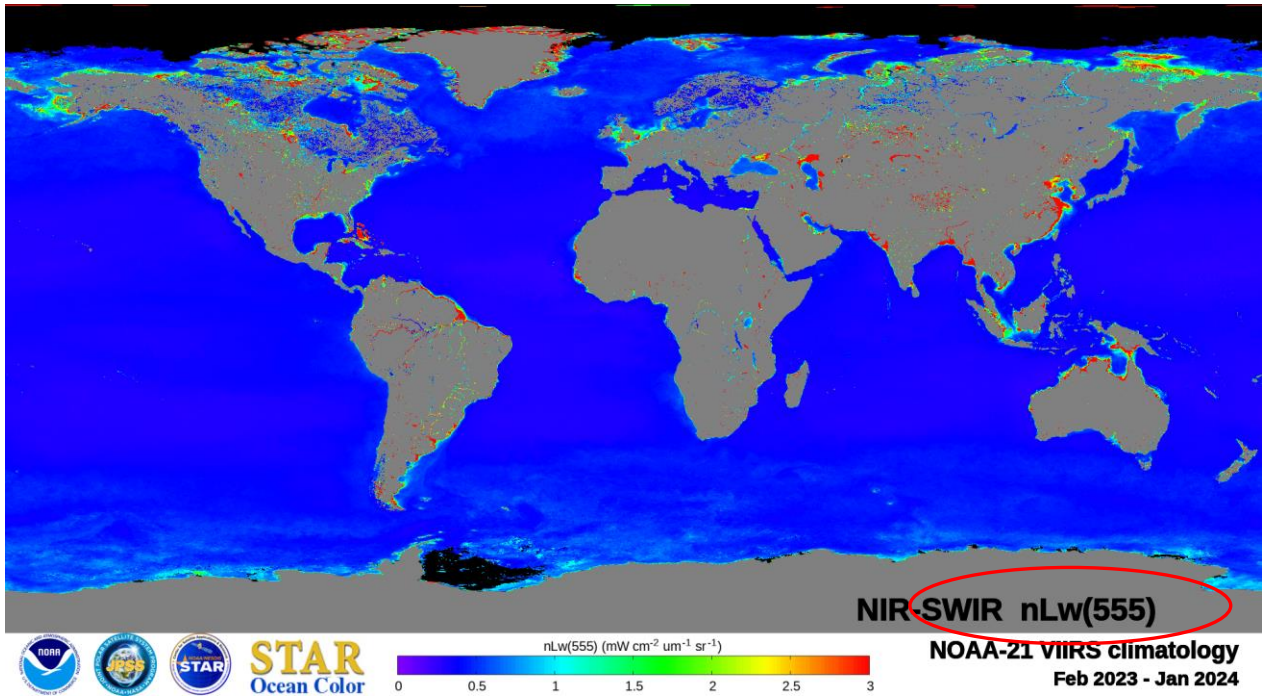
VIIRS-NOAA-21 Climatology Ocean Color Products
(Feb. 2023–Jan. 2024)

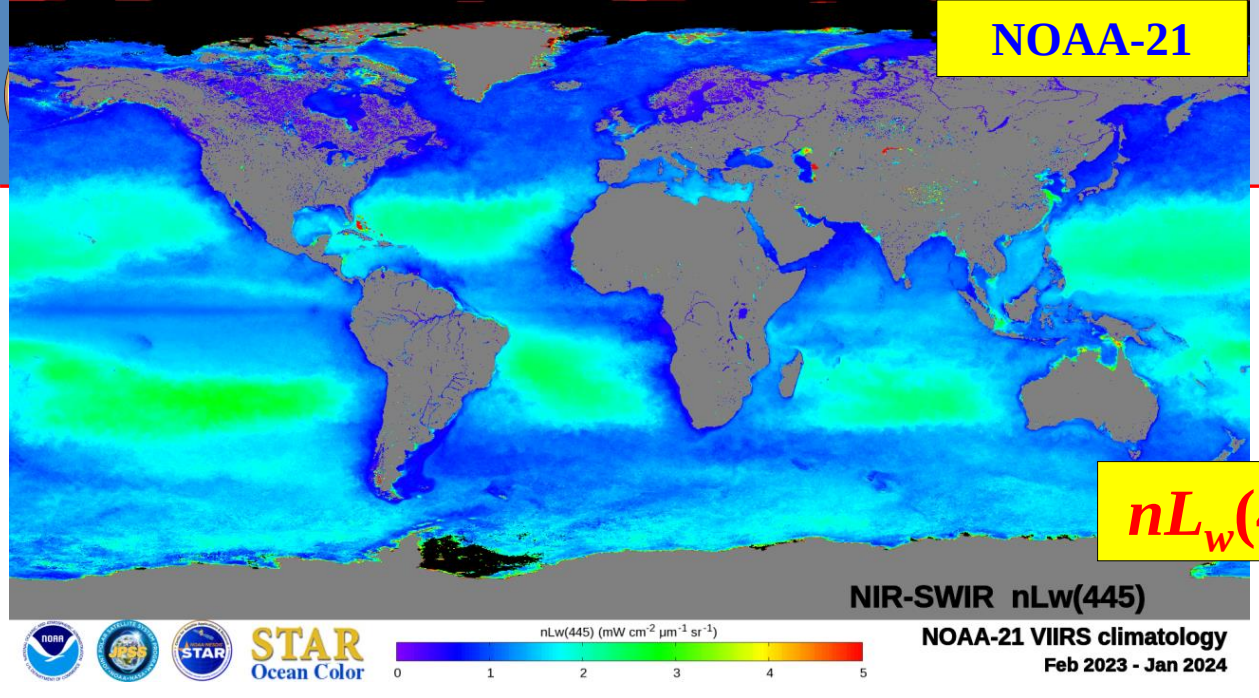


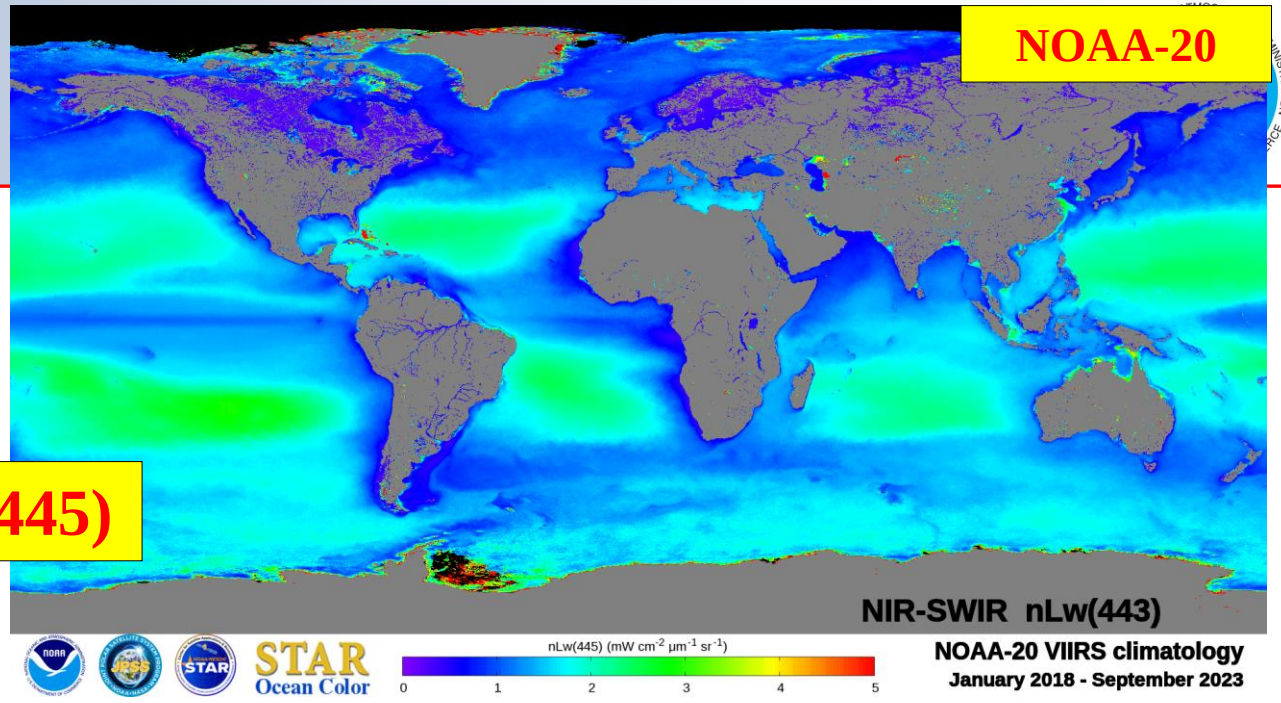

NOAA-21
NIR-SWIR nLw(411)
STAR Ocean Color
nLw(411) (mW cm-2 µm-1 sr-1)
0 1 2 3 4 5
NOAA-21 VIIRS climatology
Feb 2023 - Jan 2024


NOAA-21
NIR-SWIR nLw(445)
STAR Ocean Color
nLw(445) (mW cm-2 µm-1 sr-1)
0 1 2 3 4 5
NOAA-21 VIIRS climatology
Feb 2023 - Jan 2024

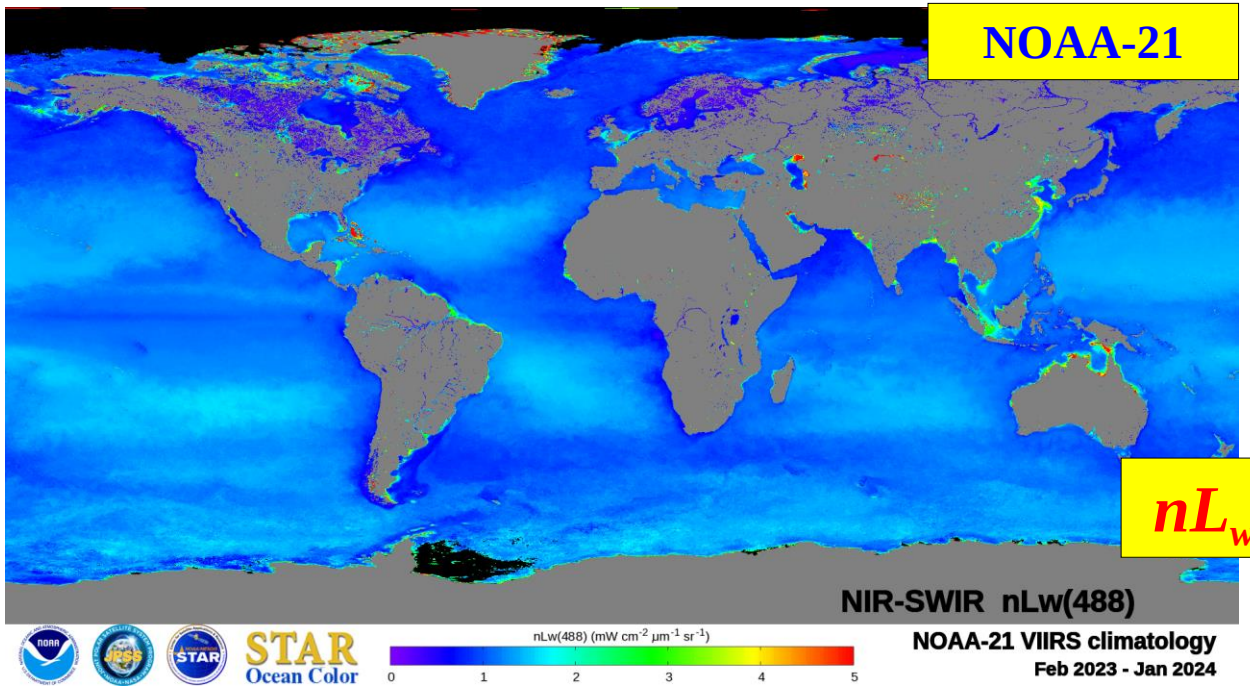

NIR-SWIR nLw(488)
STAR Ocean Color
nLw(488) (mW cm-2 µm-1 sr-1)
0 1 2 3 4 5
NOAA-21 VIIRS climatology
Feb 2023 - Jan 2024

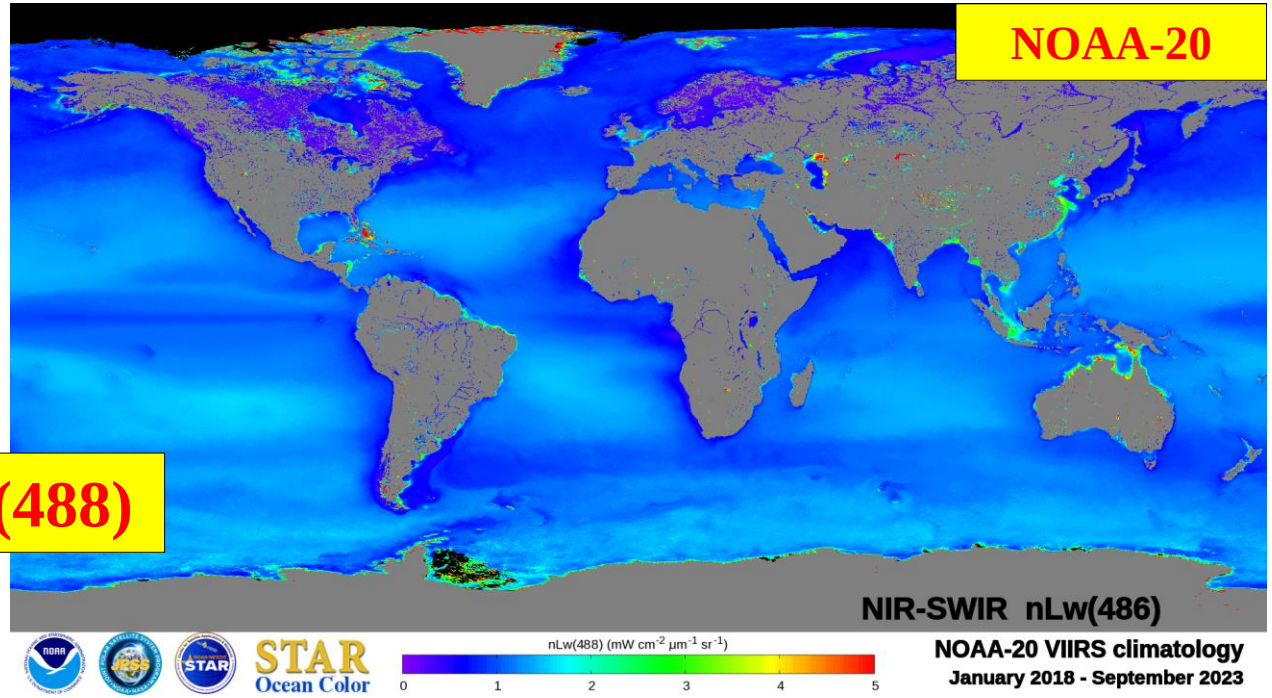

NIR-SWIR nLw(555)
STAR Ocean Color
nLw(555) (mW cm-2 um-1 sr-1)
0 0.5 1 1.5 2 2.5 3
NOAA-21 VIIRS climatology
Feb 2023 - Jan 2024



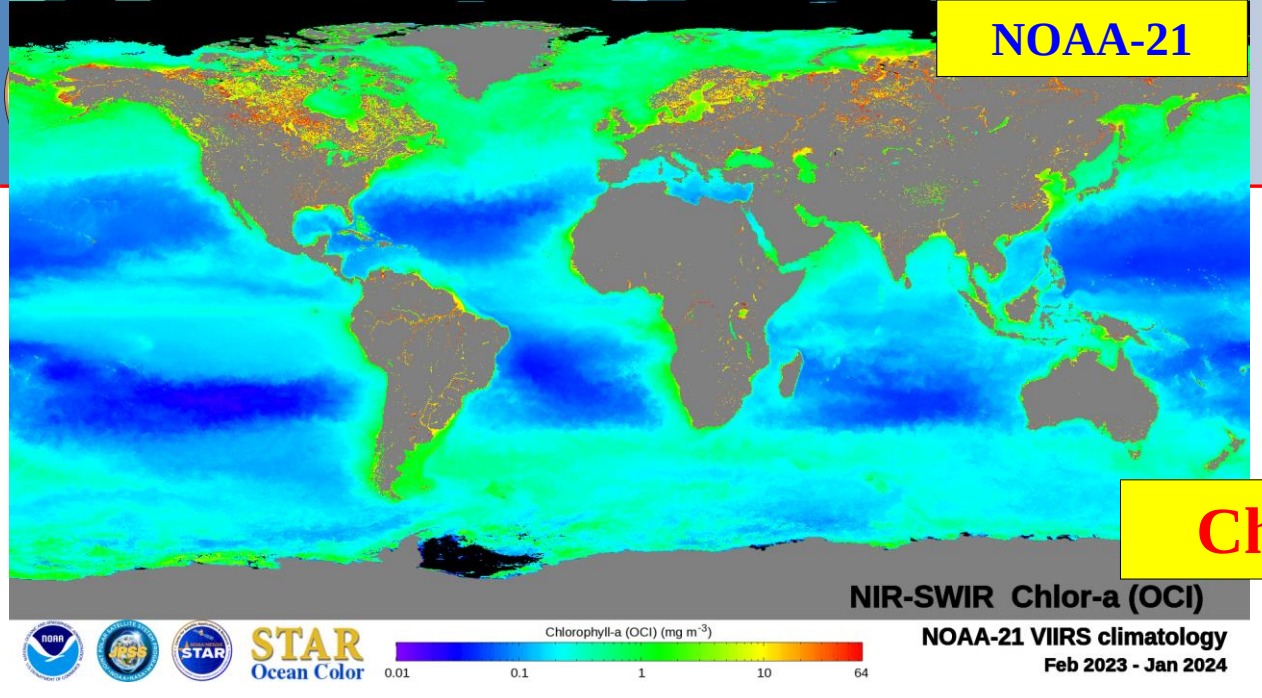


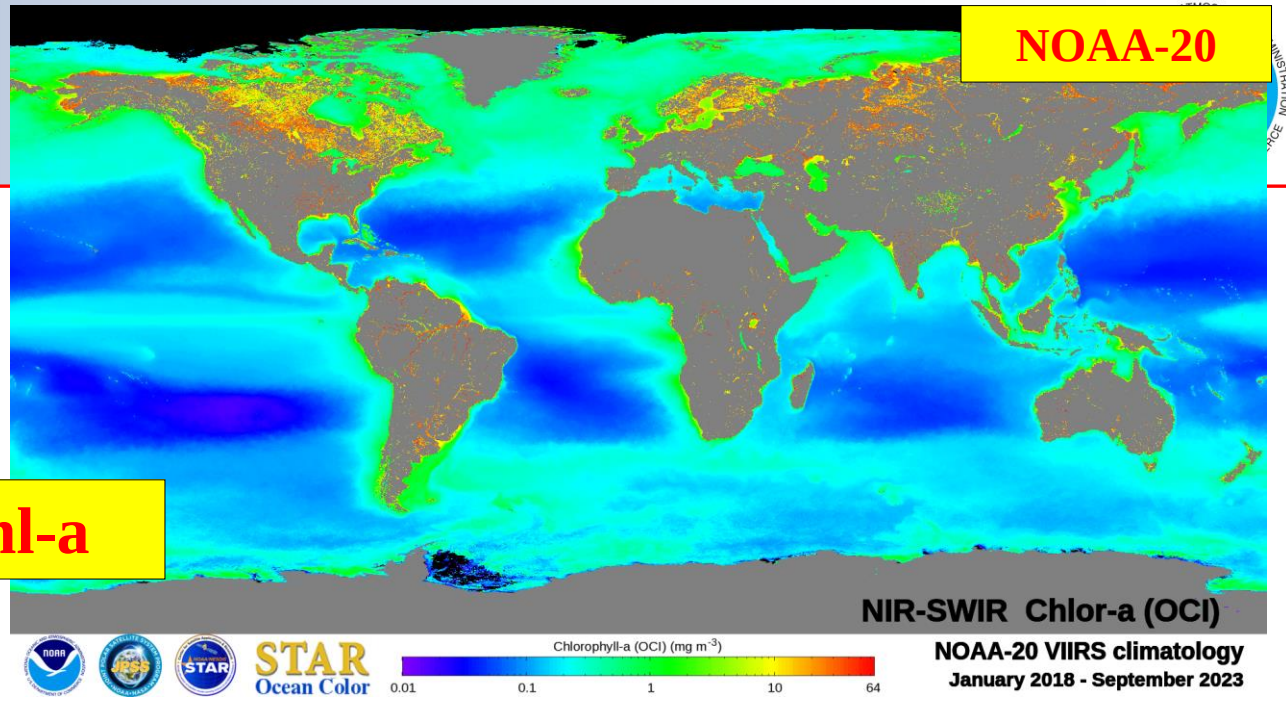
$nL_w(445)$



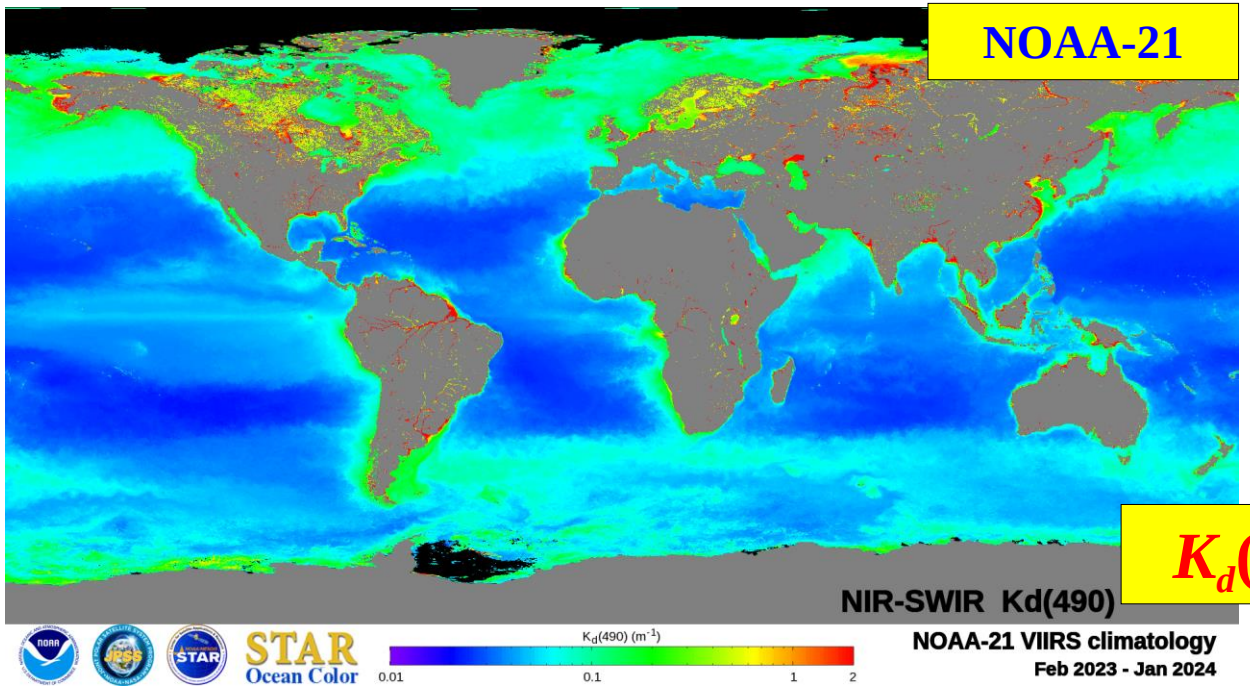


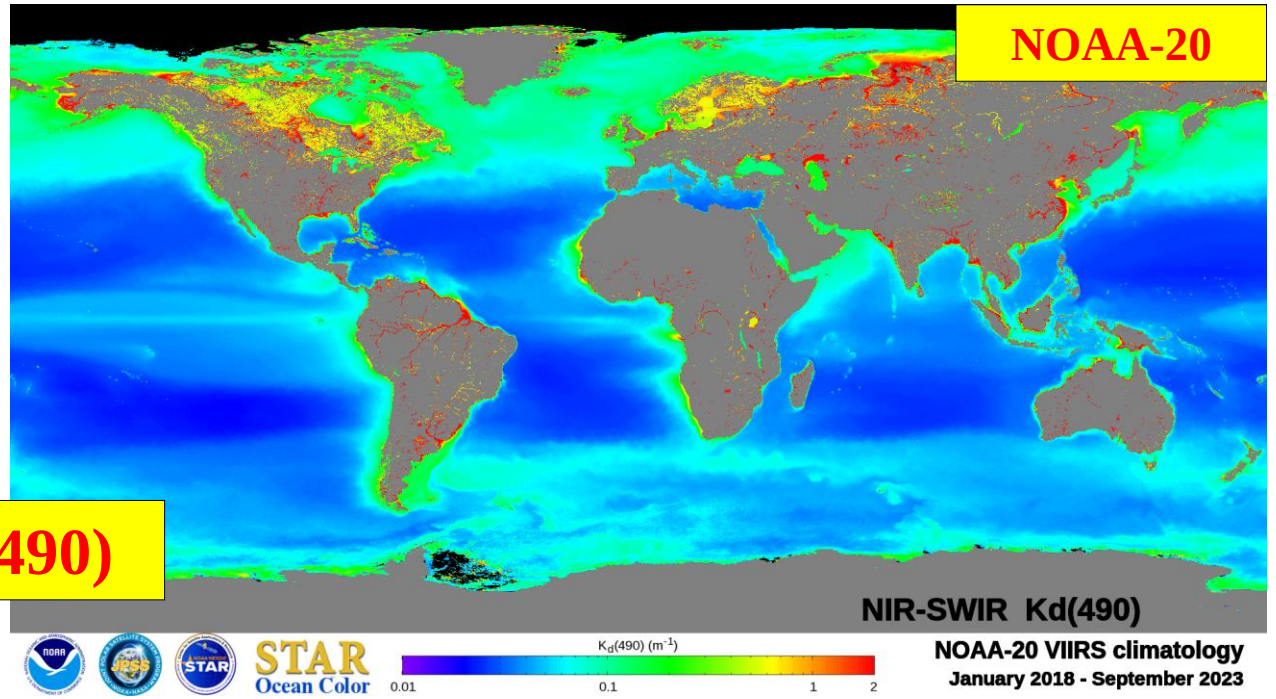
$nL_w(488)$


NOAA-21
NIR-SWIR Chlor-a (OCI)
STAR Ocean Color
Chlorophyll-a (OCI) (mg m-3)
0.01 0.1 1 10 64
NOAA-21 VIIRS climatology
Feb 2023 - Jan 2024


NOAA-20
NIR-SWIR Chlor-a (OCI)
STAR Ocean Color
Chlorophyll-a (OCI) (mg m-3)
0.01 0.1 1 10 64
NOAA-20 VIIRS climatology
January 2018 - September 2023

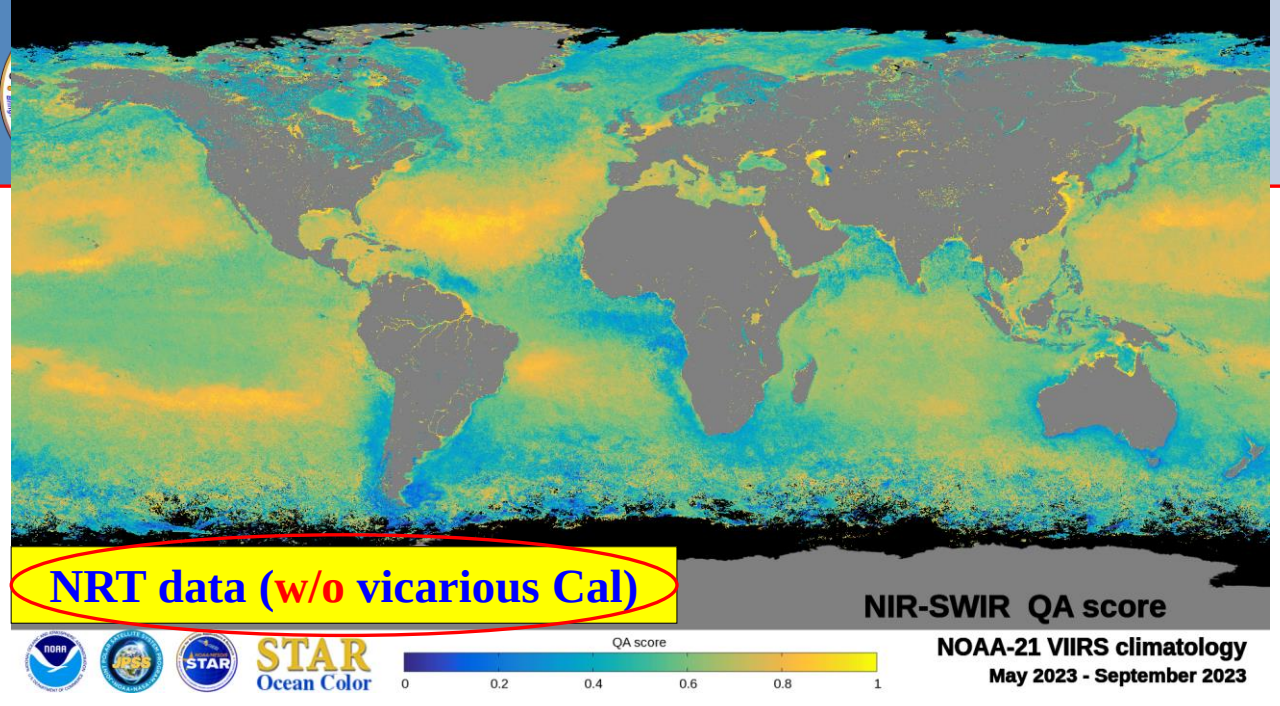
Chl-a

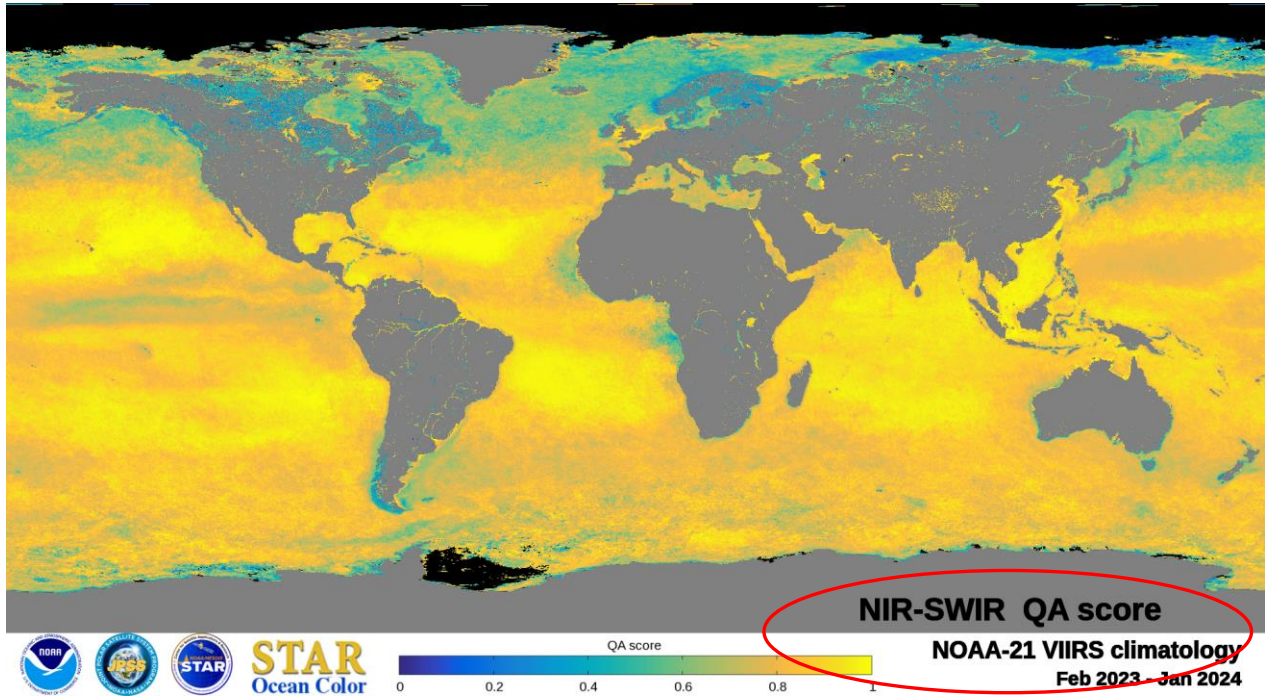

NOAA-21
NIR-SWIR Kd(490)
STAR Ocean Color
Kd(490) (m-1)
0.01 0.1 1 2
NOAA-21 VIIRS climatology
Feb 2023 - Jan 2024


NOAA-20
NIR-SWIR Kd(490)
STAR Ocean Color
Kd(490) (m-1)
0.01 0.1 1 2
NOAA-20 VIIRS climatology
January 2018 - September 2023

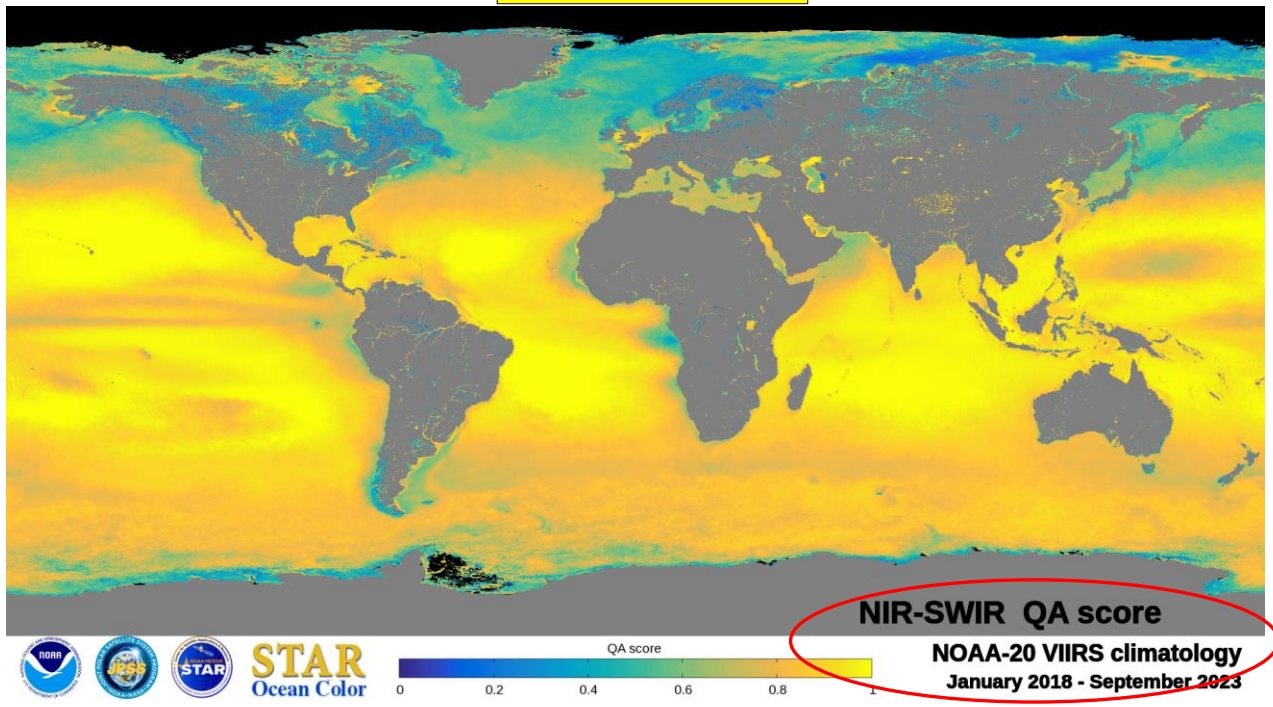
$K_d(490)$

QA Score Comparisons





NOAA-20



Ocean Color Data Performance Evaluations (1)

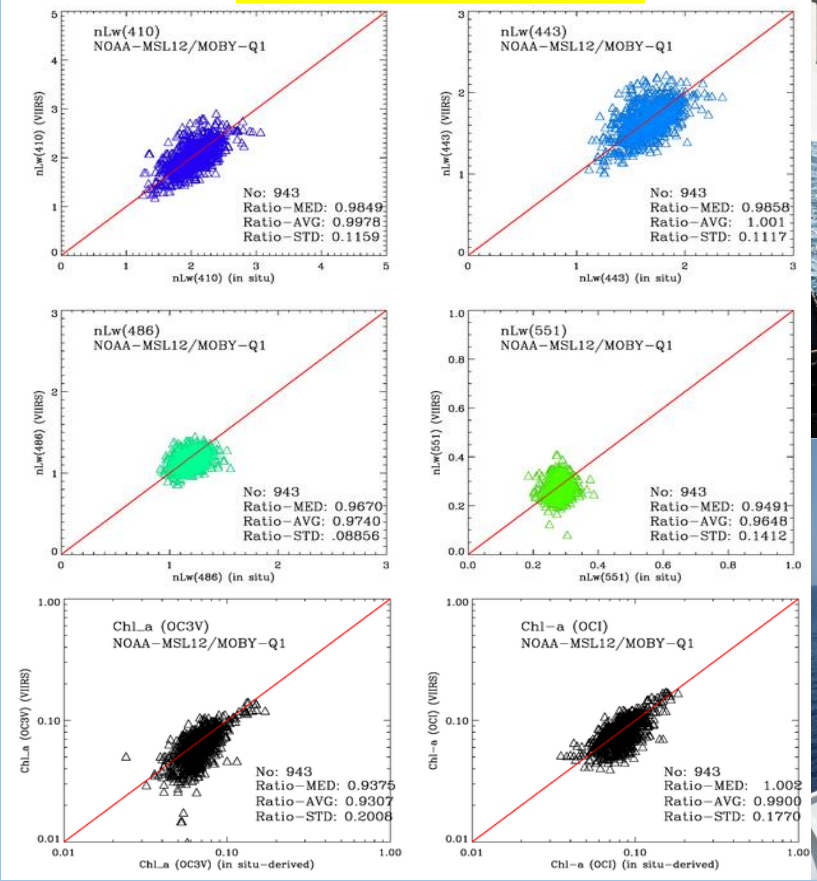
(NOAA-21 compared with MOBY **in situ data**)

- Ocean color data from VIIRS-NOAA-21 are being routinely compared with in situ measurements from the Marine Optical Buoy (MOBY) in Hawaii (oligotrophic water).
- MOBY in situ data have high data quality and considered as “truth”. However, there are limited in situ data available for VIIRS-NOAA-21 period (currently all noted as Q2).
- Using the limited MOBY in situ data (high quality data), VIIRS-NOAA-21 ocean color products are evaluated for period starting on Feb. 2023.
- Evaluation results (from comparisons with MOBY in situ data) show that VIIRS-NOAA-21 ocean color data compared well with MOBY in situ measurements.
- Results show strong spectral correlation for errors in VIIRS-NOAA-21-derived normalized water-leaving radiance spectra.

NOAA Ocean Color Cal/Val Activities

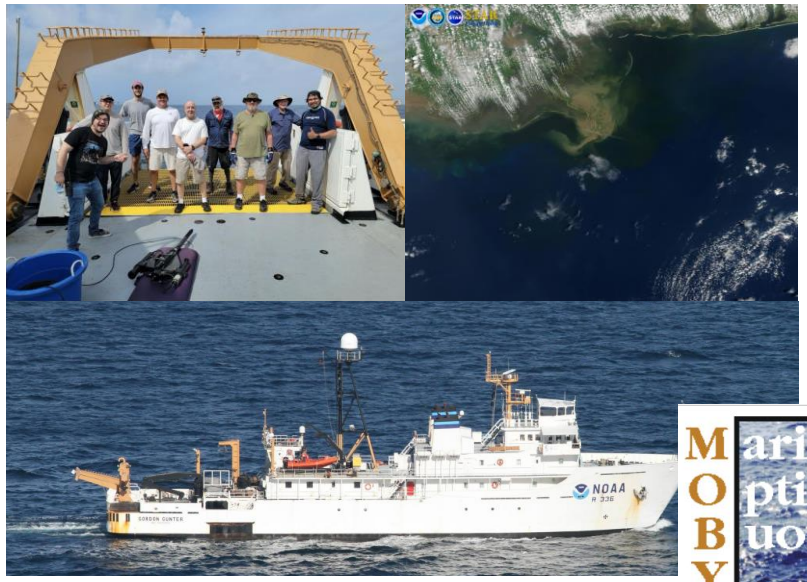
- Routine **MOBY** in situ measurements (critical in situ data)
- Complete **eight** dedicated annual Cal/Val cruises (2014-2023)
- Participating various in situ measurement opportunities
- Four **AERONET-OC** sites in situ data measurements
- Routine monitoring of VIIRS, OLCI, SGLI, etc. ocean color data performance using in situ data

MOBY Matchup Data

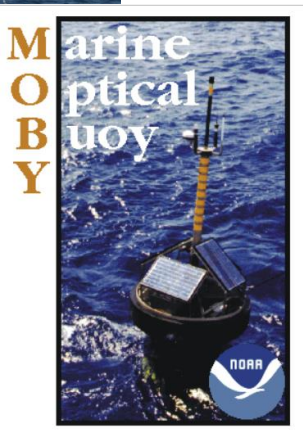


NOAA Technical Report NESDIS 157
DOI: 10.25923/x2q6-9418

Report for
Dedicated JPSS VIIRS Ocean Color Calibration/Validation Cruise:
Gulf of Mexico in April 2021



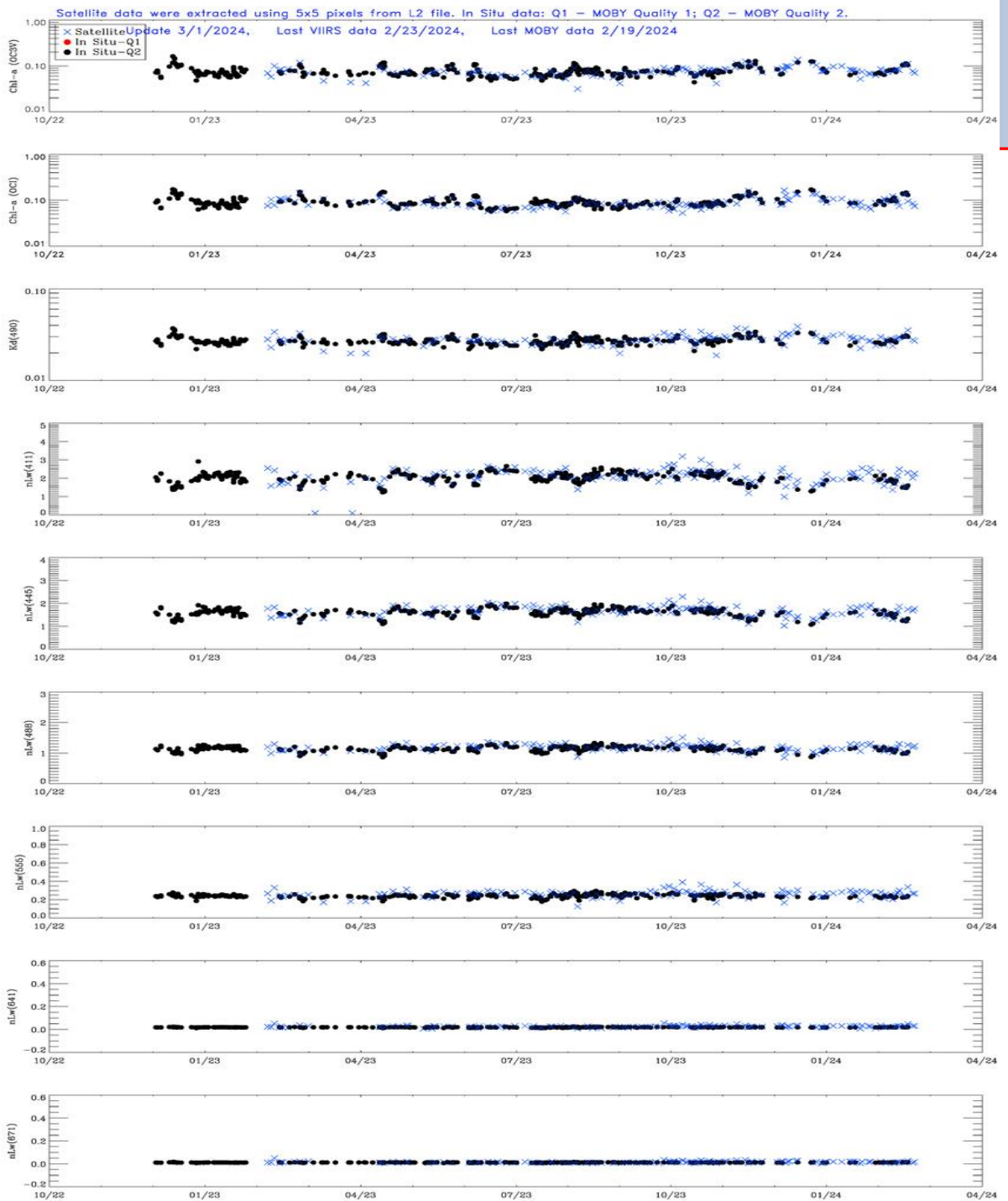
Washington, D.C.
October 2022

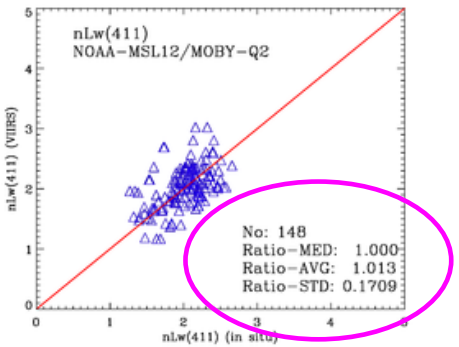


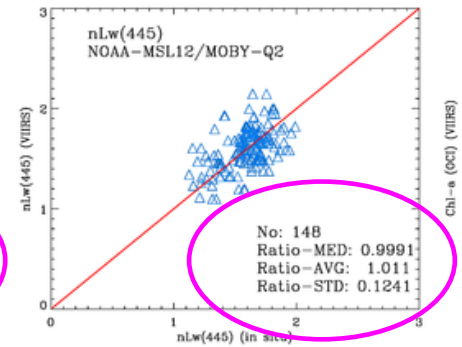
US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Serv

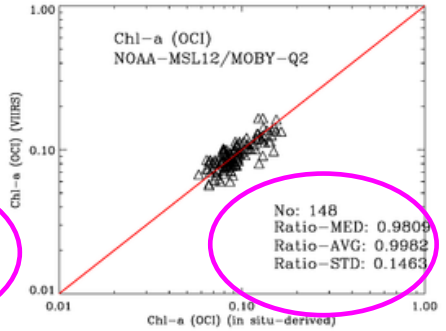
Ondrusek *et al*., "Report for Dedicated JPSS VIIRS Ocean Color Calibration/ Validation Cruise: Gulf of Mexico in April 2021," ***NOAA Technical Report NESDIS*** *157*, J. Wei (ed.), NOAA NESDIS, Silver Spring, Maryland, October 2022. https://doi.org/10.25923/x2q6-9418

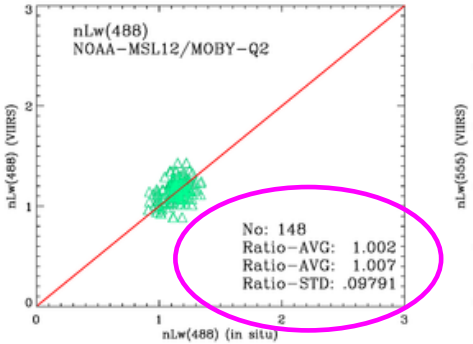
Matchup Comparisons of VIIRS-NOAA-21 & MOBY In Situ (Q2)

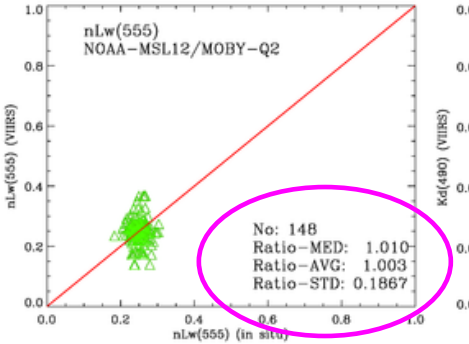


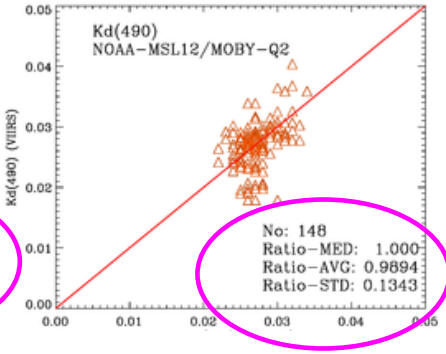


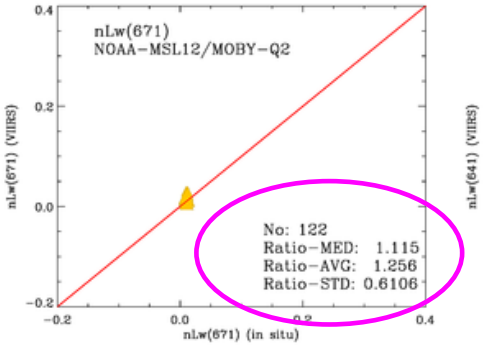


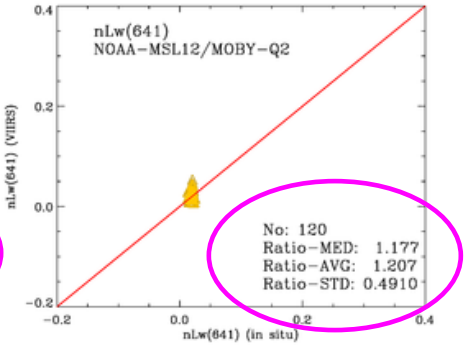








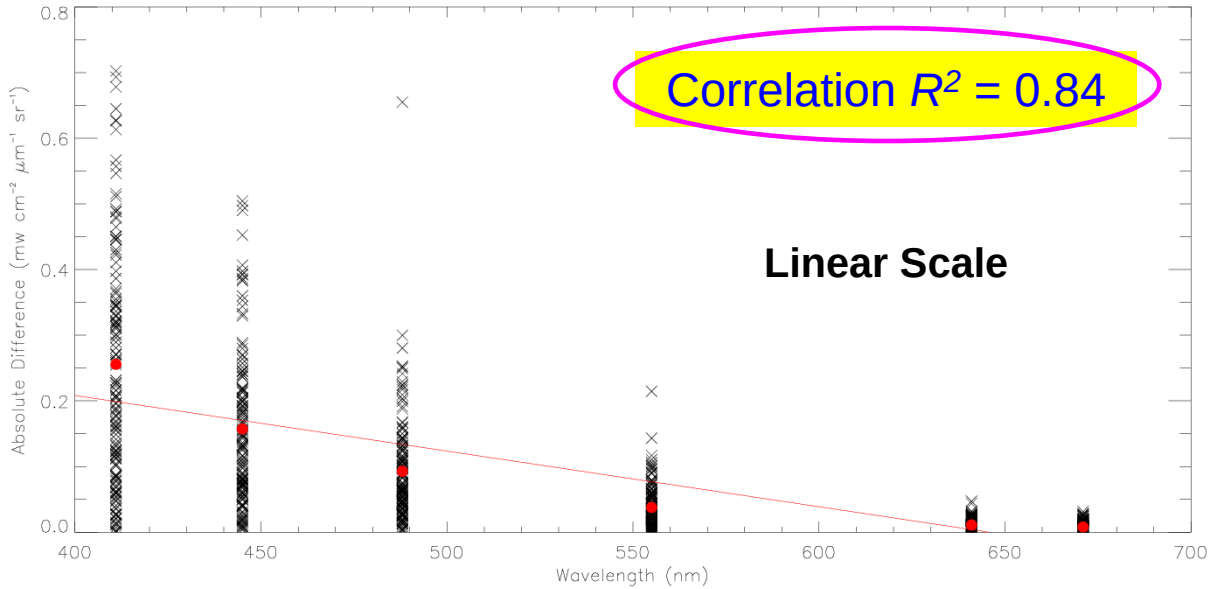


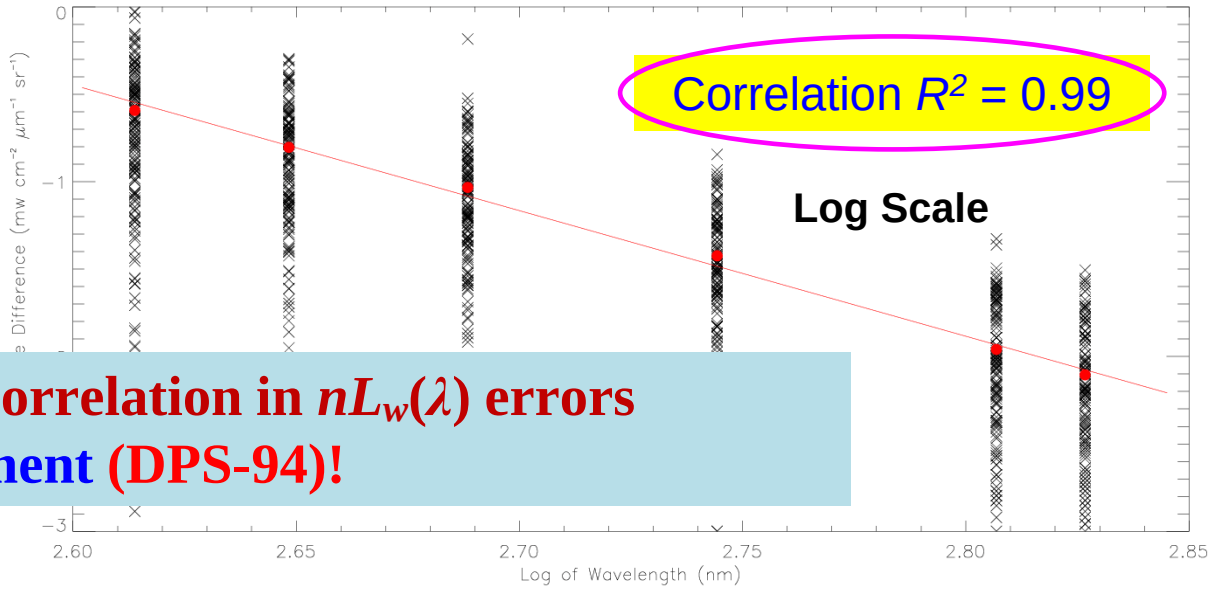


(Black: In Situ; Blue: **NOAA-21**)

Absolute Difference between VIIRS NOAA-21 & MOBY In situ data

Product	AVG	No
$nL_w(411)$	0.2556	151
$nL_w(445)$	0.1572	151
$nL_w(488)$	0.0927	151
$nL_w(555)$	0.0377	151
$nL_w(641)$	0.0110	151
$nL_w(671)$	0.0078	151





MOBY In Situ Data (Q2)

(13 Feb 2023 to 11 Feb 2024)

Results show strong spectral correlation in $nL_w(\lambda)$ errors
Meet the requirement (DPS-94)!

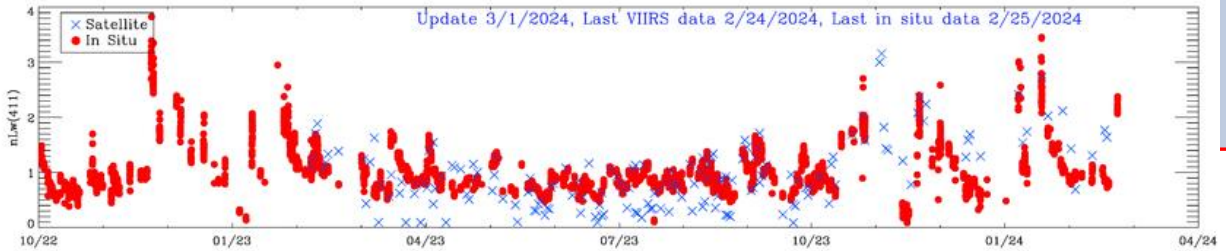
*Red-filled circles are **Mean** difference

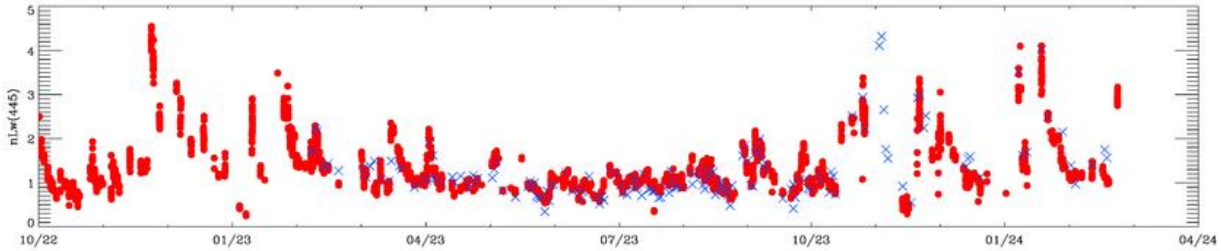
Ocean Color Data Performance Evaluations (2)

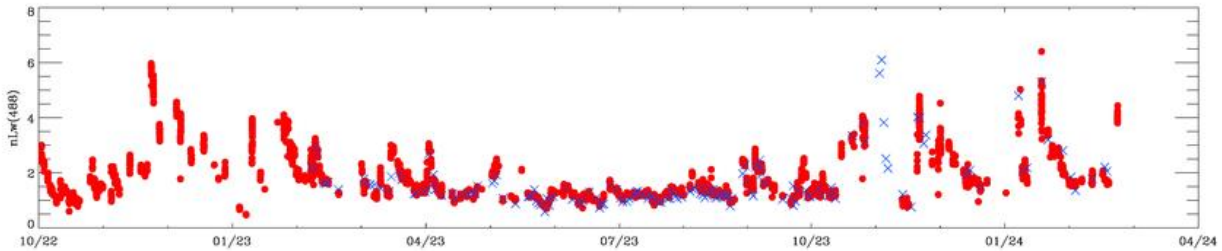
(NOAA-21 compared with AERONET-OC in situ data)

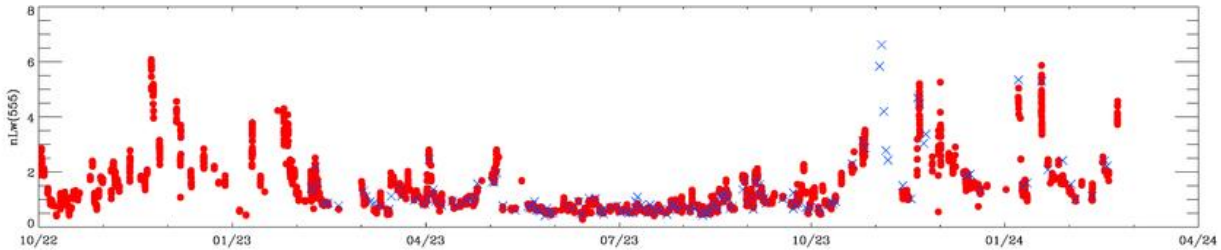
- Ocean color data from VIIRS-NOAA-21 are being routinely compared with in situ measurements from various AERONET-OC data (coastal and inland waters).
- We show NOAA-21 OC comparison results with three AERONET-OC sites: AAOT, LISCO, and Lake Erie.
- Evaluation results (with AERONET-OC in situ data) show that VIIRS-NOAA-21 ocean color data compared generally reasonable with the in situ measurements (over coastal and inland waters).

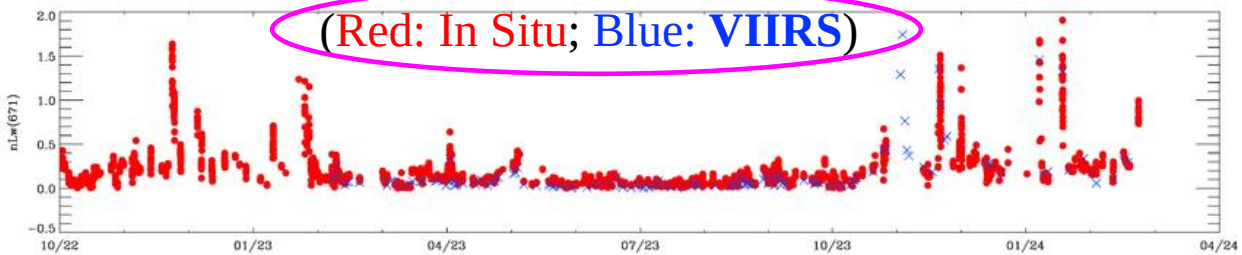
Matchup Comparisons of VIIRS-NOAA-21 & AERONET-OC AAOT In Situ



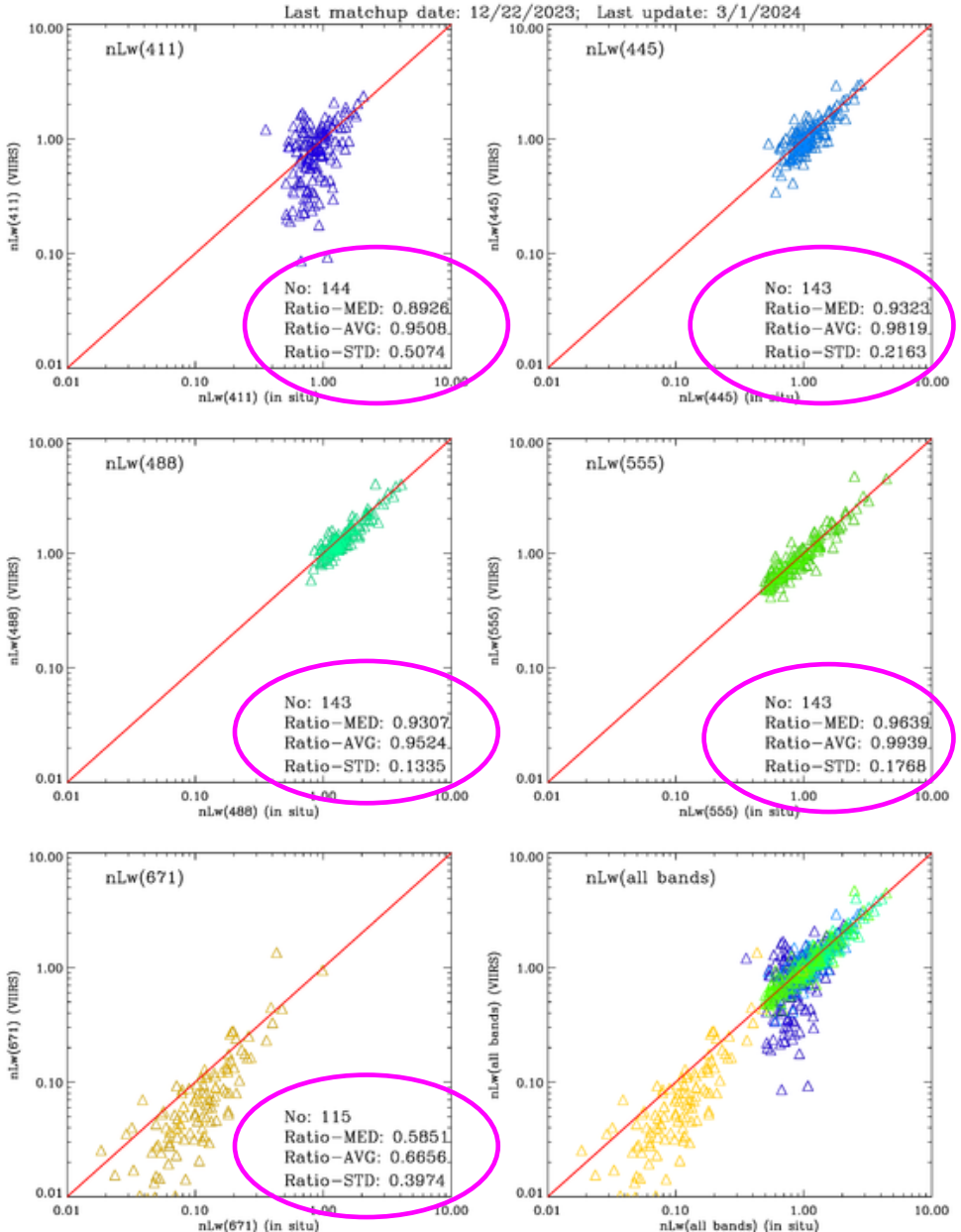




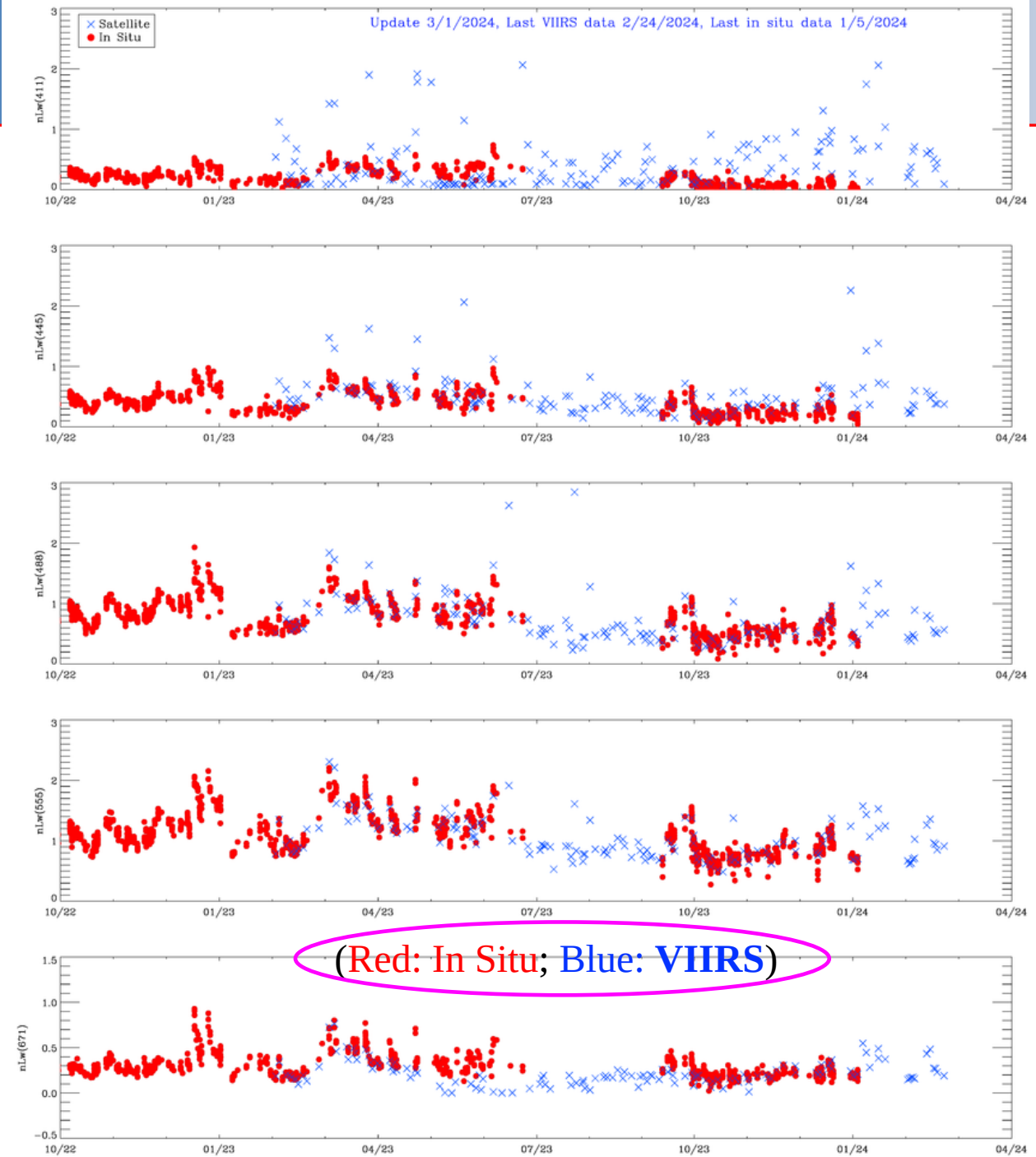




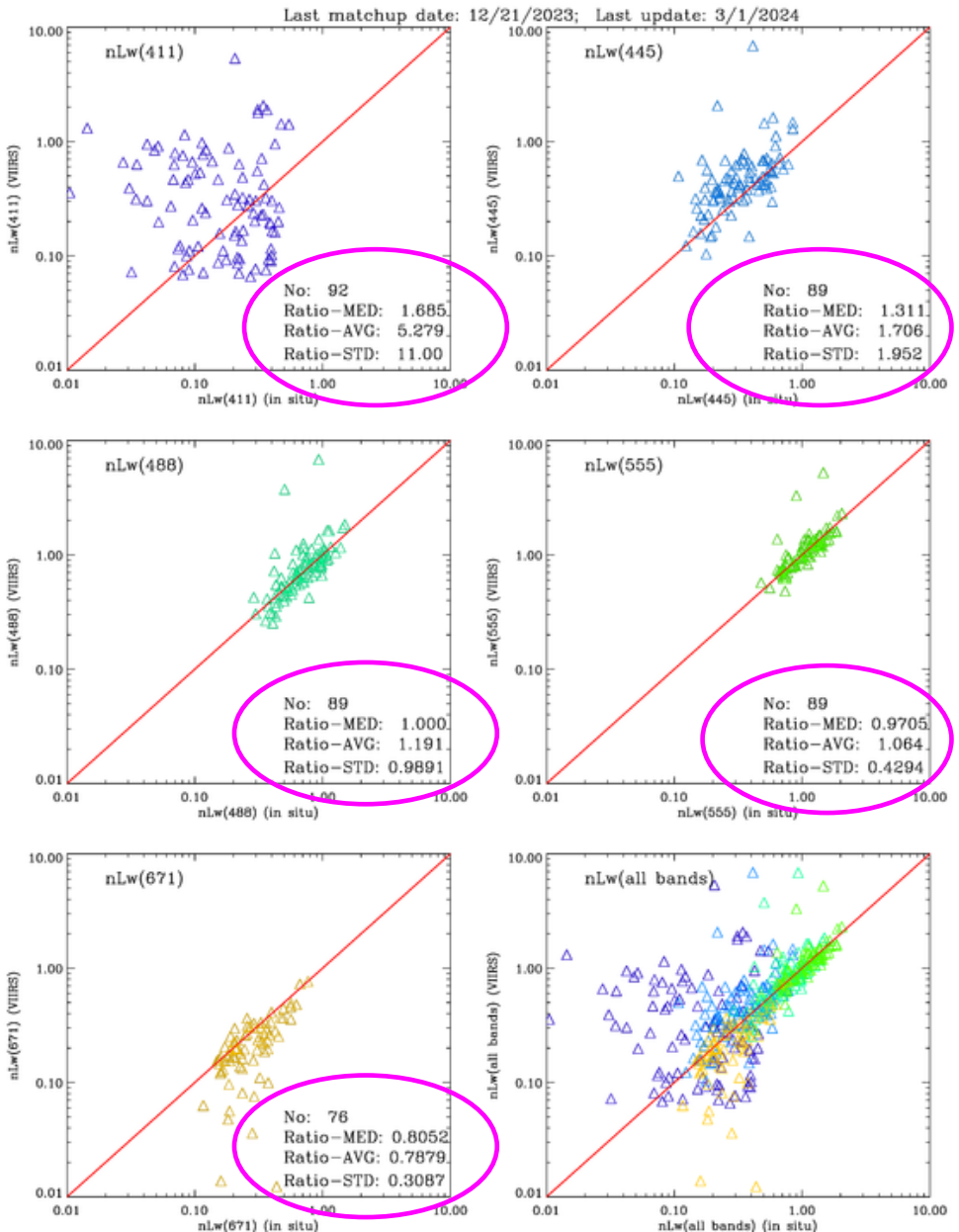
(Red: In Situ; Blue: **VIIRS**)



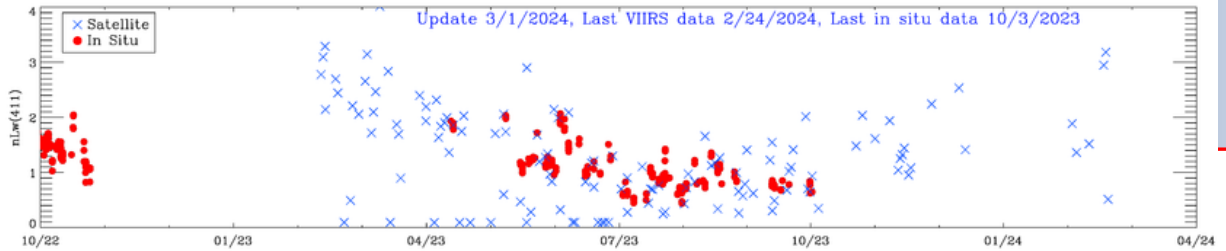
Matchup Comparisons of VIIRS-NOAA-21 & AERONET-OC LISCO In Situ

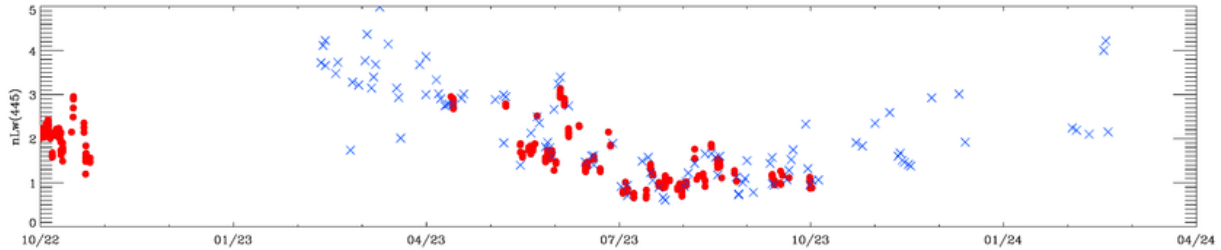


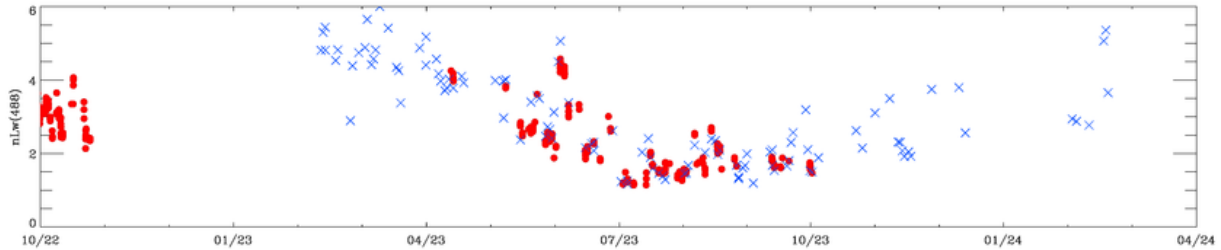
(Red: In Situ; Blue: **VIIRS**)

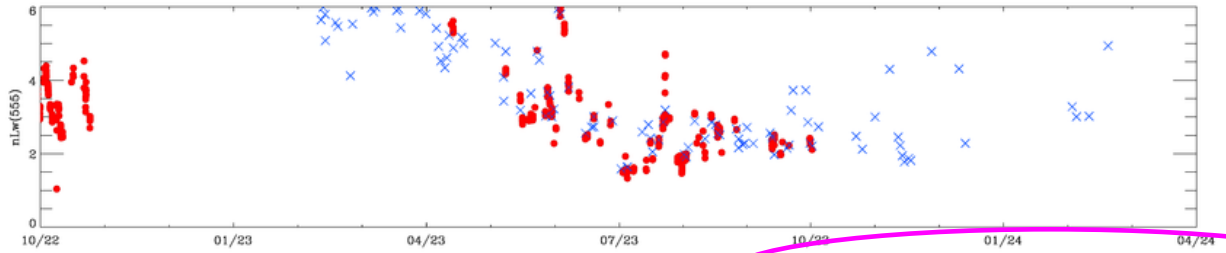


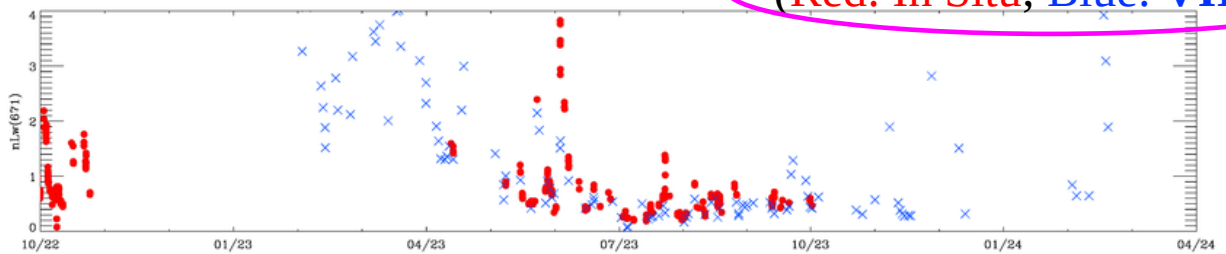
Matchup Comparisons of VIIRS-NOAA-21 & AERONET-OC Lake Erie In Situ



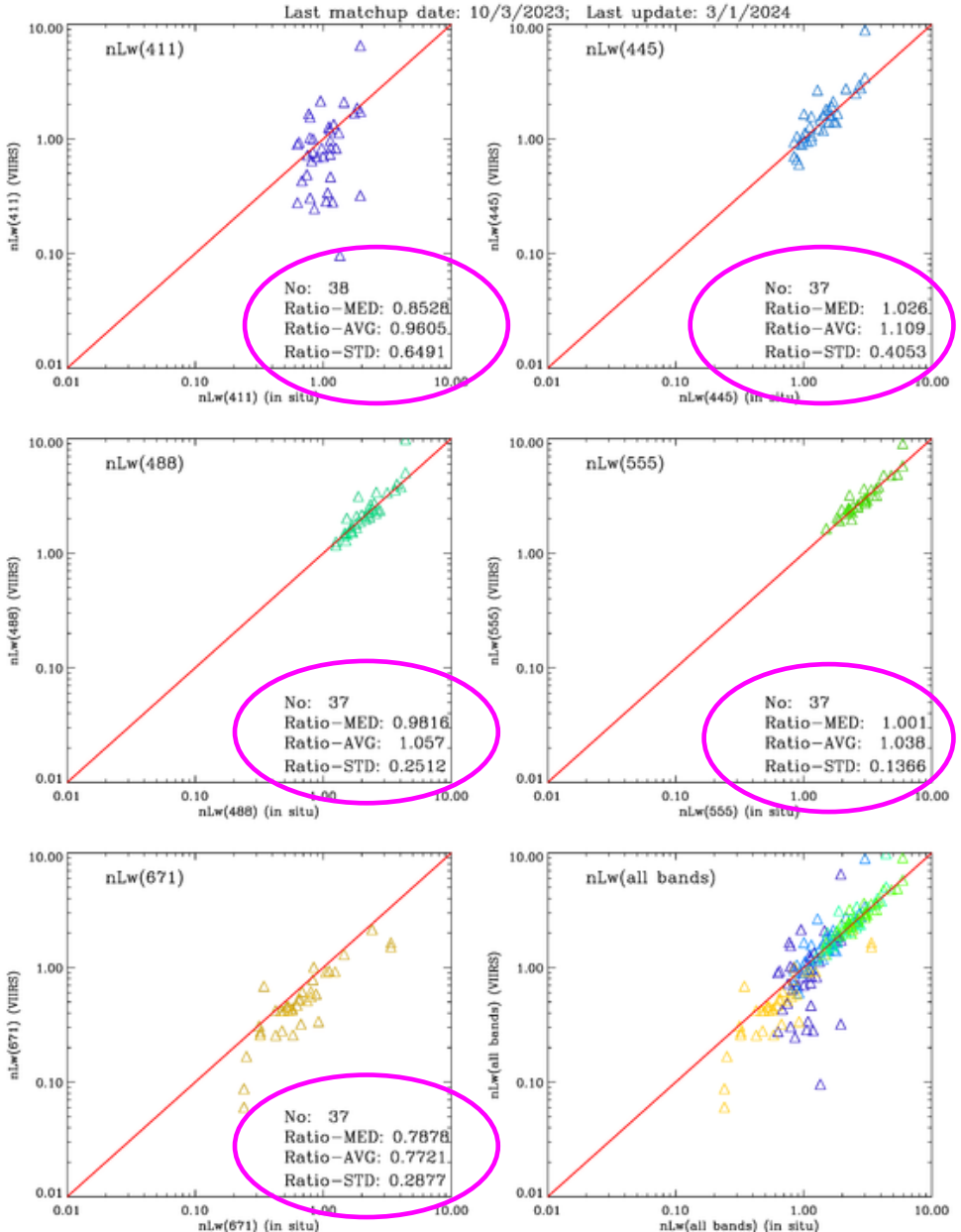








(Red: In Situ; Blue: **VIIRS**)



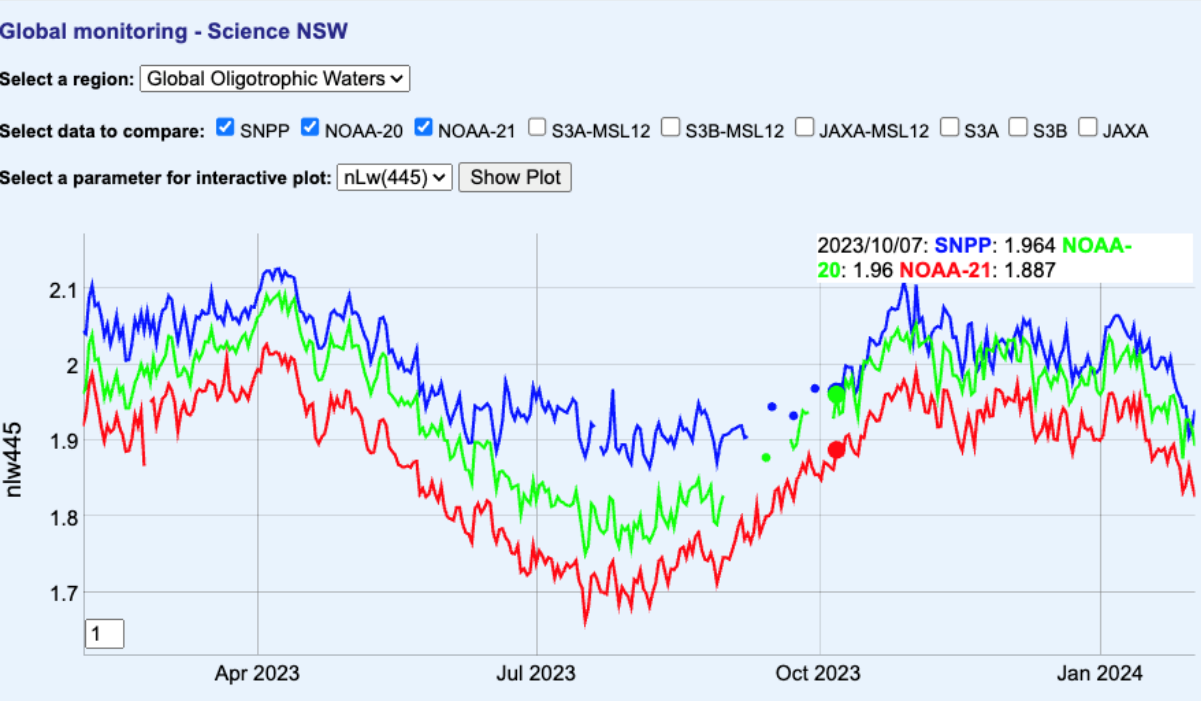
Ocean Color Data Performance Evaluations (3)

(NOAA-21 compared with NOAA-20/SNPP)

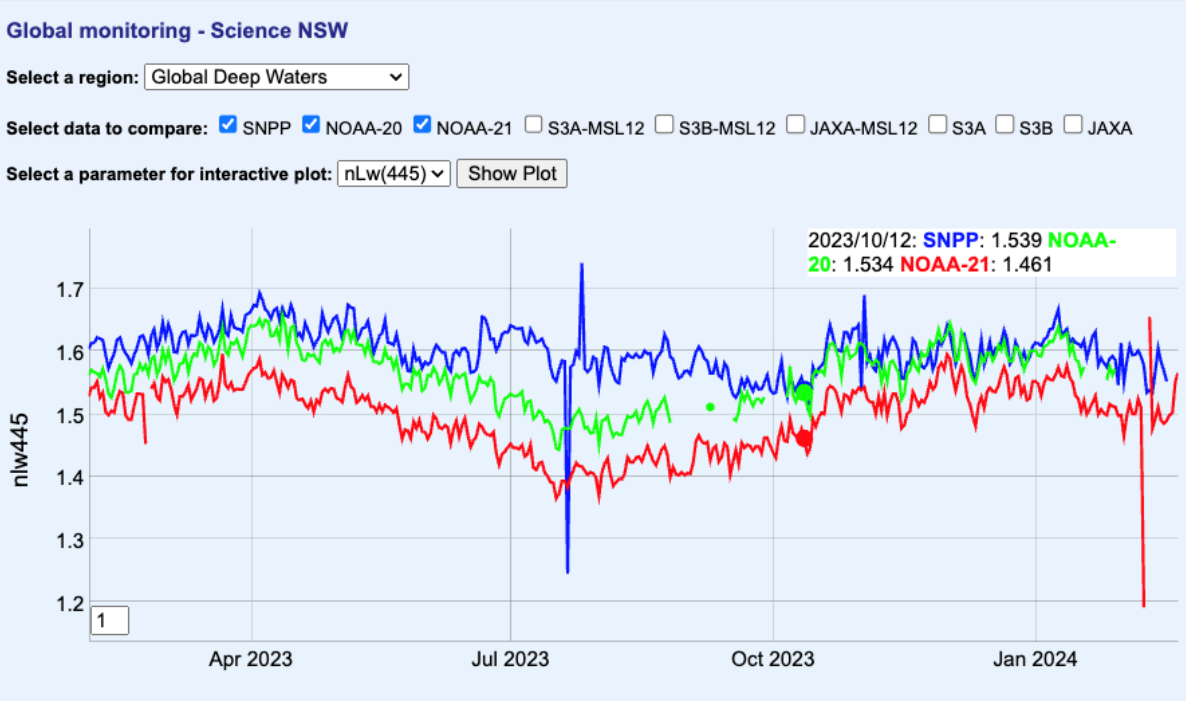
- We show OC evaluation results for NOAA-21 versus NOAA-20/SNPP over global scales (global oligotrophic oceans and global deep waters).
- We show some OC evaluation results for NOAA-21 versus NOAA-20/SNPP over regional scales (US East Coast and Mid Chesapeake Bay).
- We show statistical results from global OC data comparisons.

$nL_w(445)$ Comparisons (NOAA-21, NOAA-20, SNPP)

Global Oligotrophic Oceans



Global Deep Waters

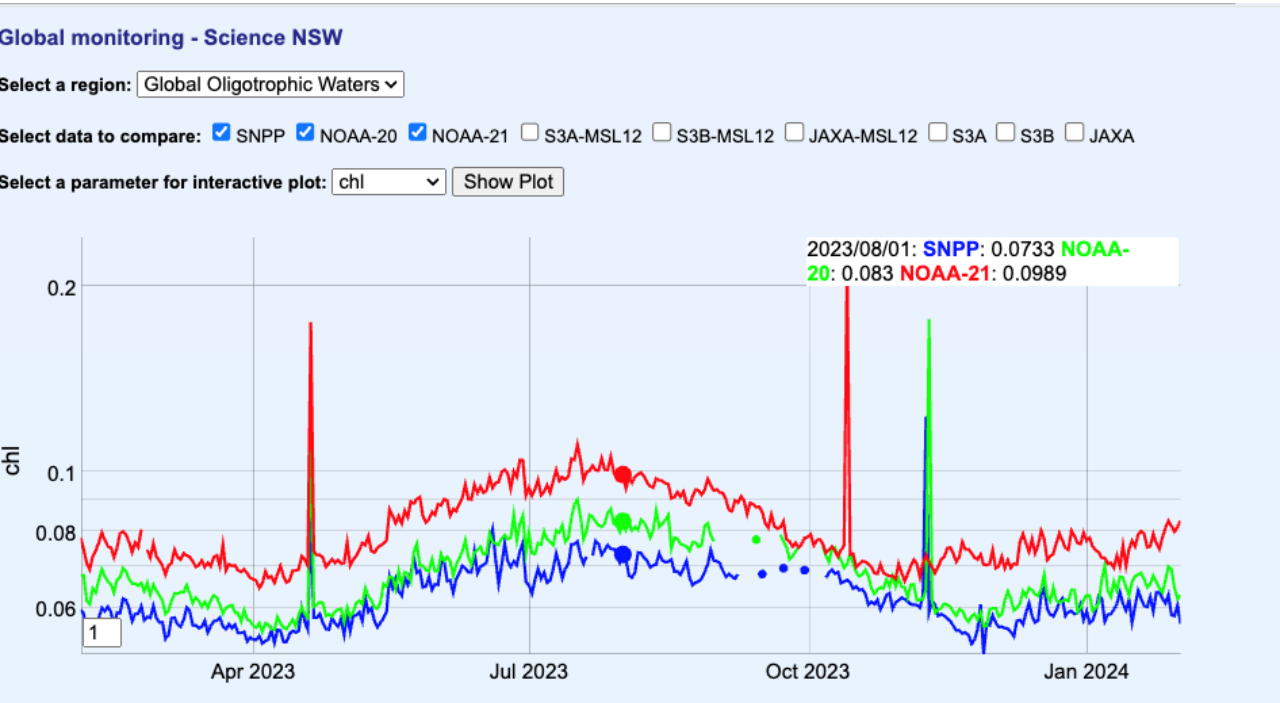


Over global oligotrophic oceans, $nL_w(445)$ are differed ~ < 5% (NOAA-21 vs. NOAA-20)

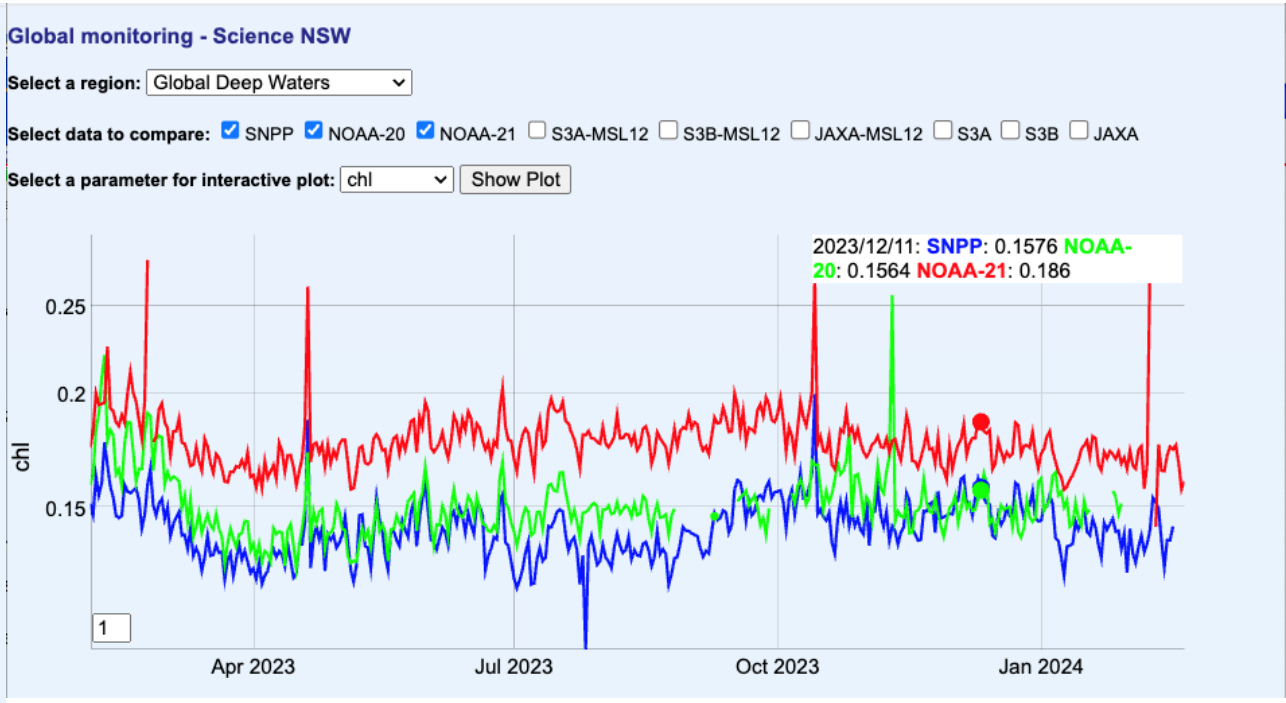
Over global deep oceans, $nL_w(445)$ are differed ~ <5% (NOAA-21 vs. NOAA-20)

Chl-a Comparisons (NOAA-21, NOAA-20, SNPP)

Global Oligotrophic Oceans



Global Deep Waters



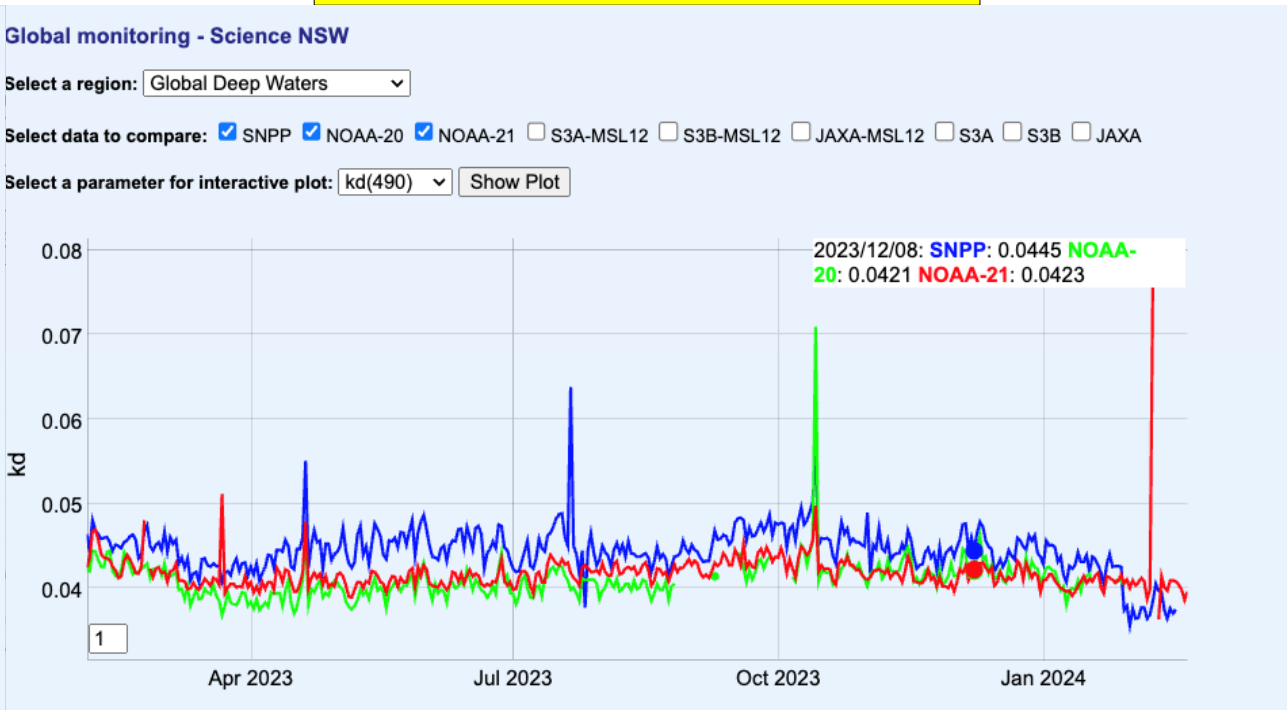
Over global oligotrophic oceans, Chl-a are differed ~0.015 mg/m^3 or ~19% (NOAA-21 vs. NOAA-20)

Over global deep oceans, Chl-a are differed ~0.03 mg/m^3 or ~19% (NOAA-21 vs. NOAA-20)

K_d(490) Comparisons (NOAA-21, NOAA-20, SNPP)

Global Oligotrophic Oceans

Global Deep Waters

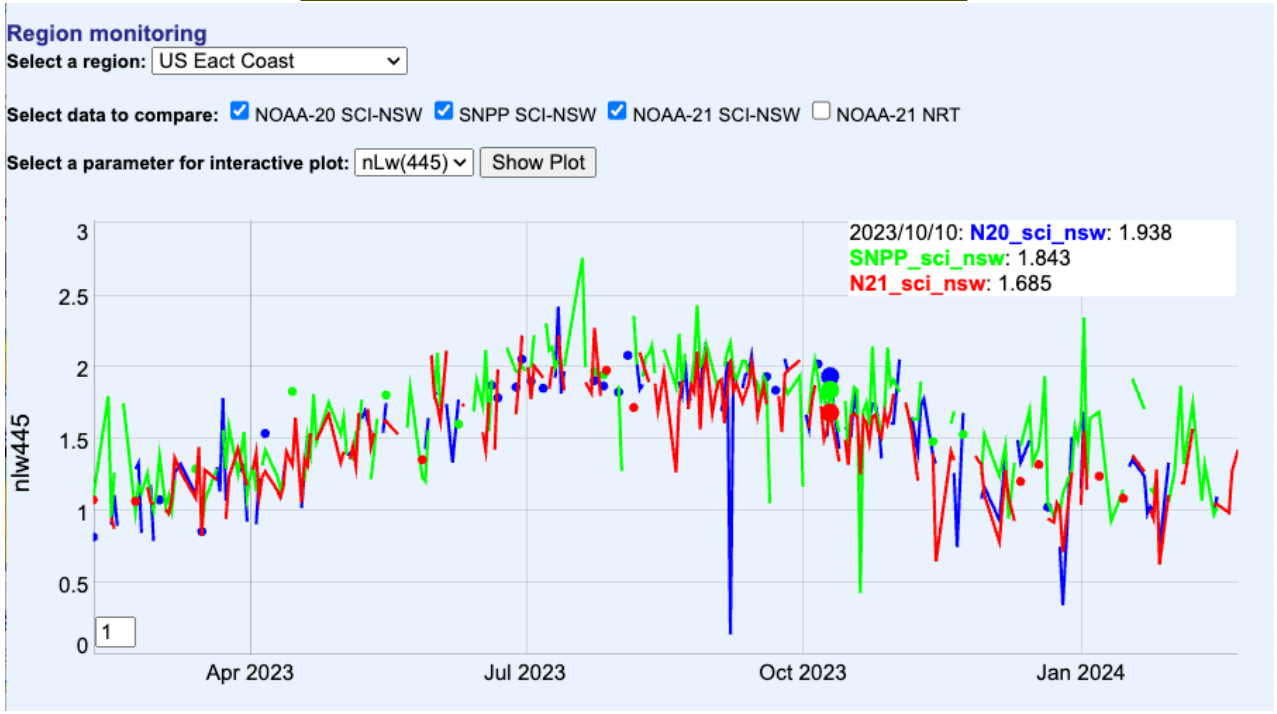


Over global oligotrophic oceans, K_d(490) are mostly **same** (NOAA-21 vs. NOAA-20)

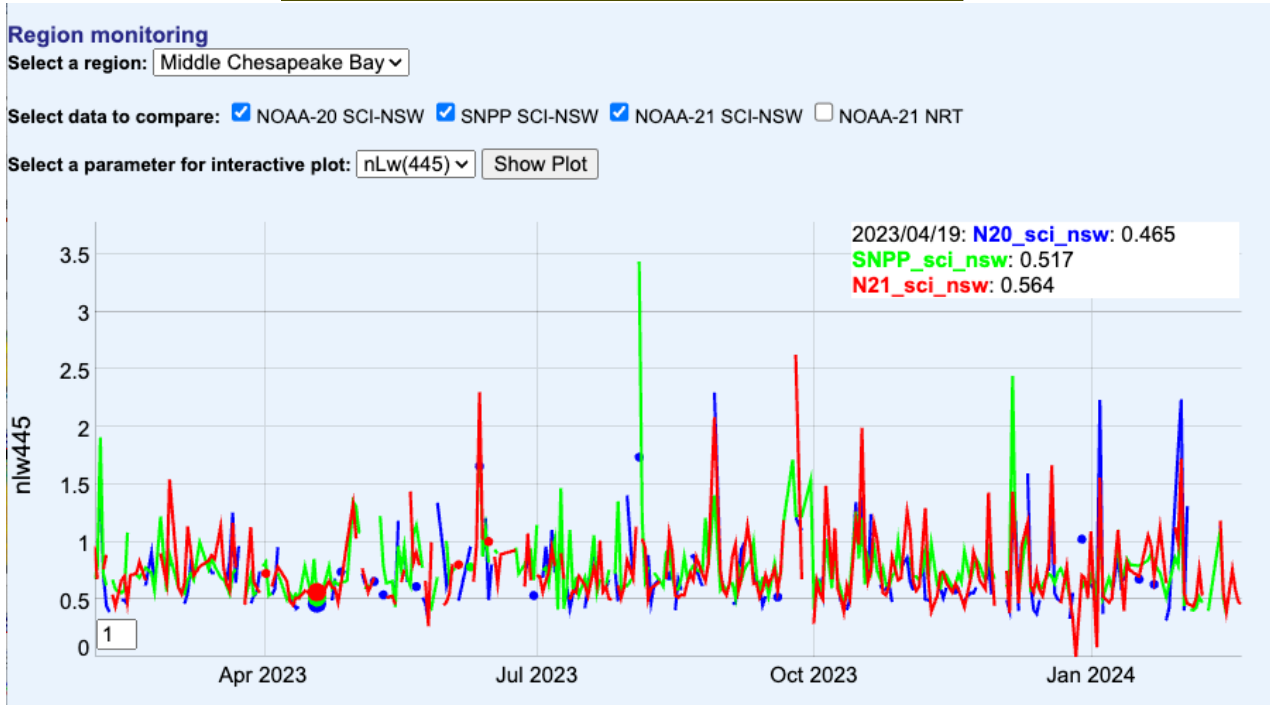
Over global deep oceans, K_d(490) are mostly **same** (NOAA-21 vs. NOAA-20)

$nL_w(445)$ Comparisons (NOAA-21, NOAA-20, SNPP)

Regional: US East Coast



Regional: Mid Chesapeake Bay

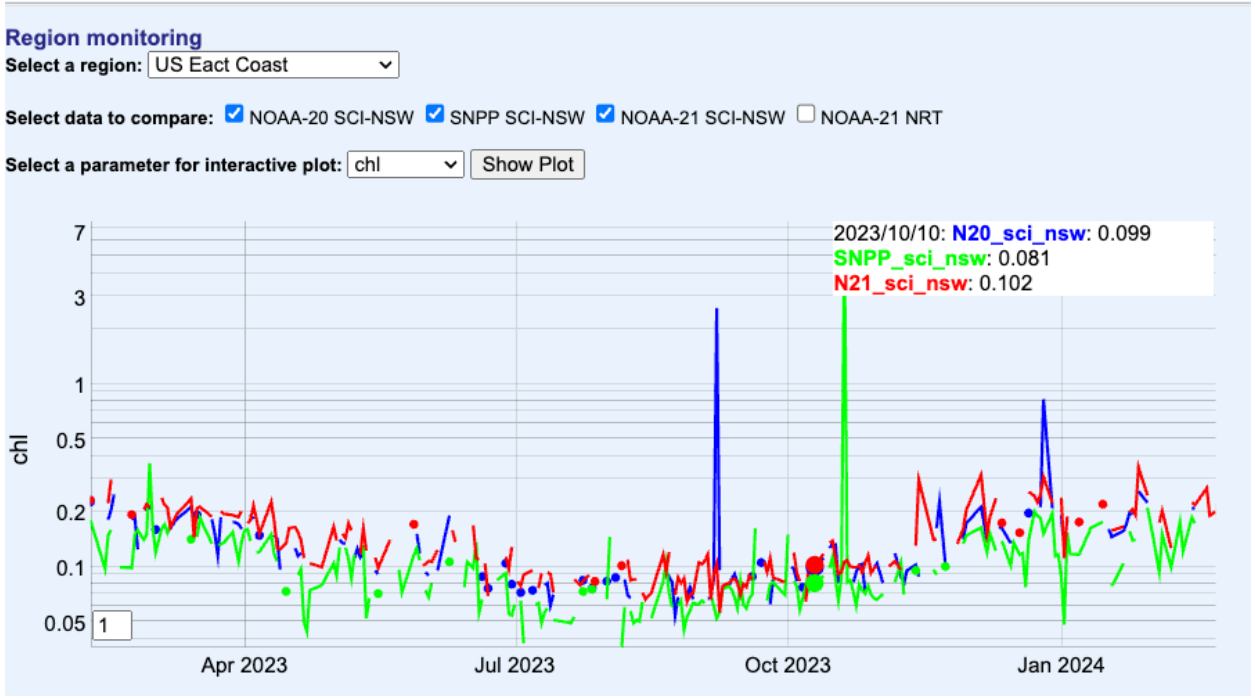


Over US East Coast, $nL_w(445)$ are differed ~13% (NOAA-21 vs. NOAA-20)

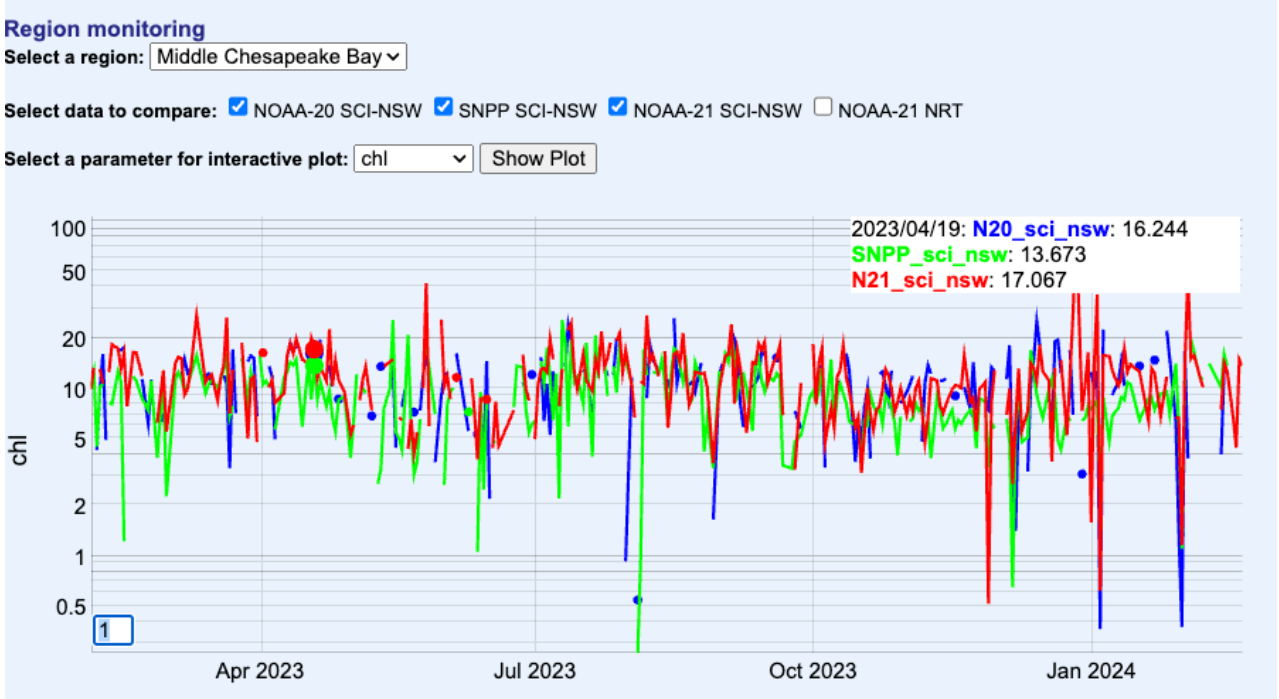
Over Mid Chesapeake Bay, $nL_w(445)$ are differed ~21% (NOAA-21 vs. NOAA-20)

Chl-a Comparisons (NOAA-21, NOAA-20, SNPP)

Regional: US East Coast



Regional: Mid Chesapeake Bay

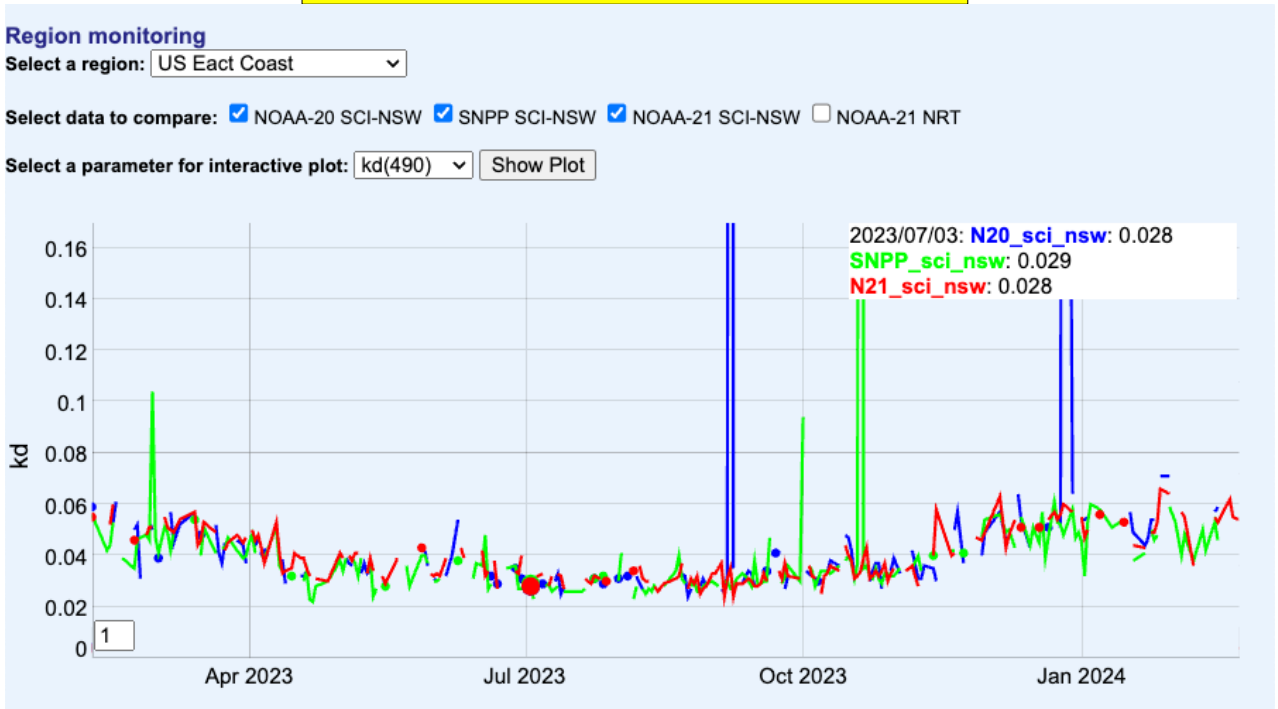


Over the US East Coast, Chl-a are differed ~0.003 mg/m^3 or ~3% (NOAA-21 vs. NOAA-20)

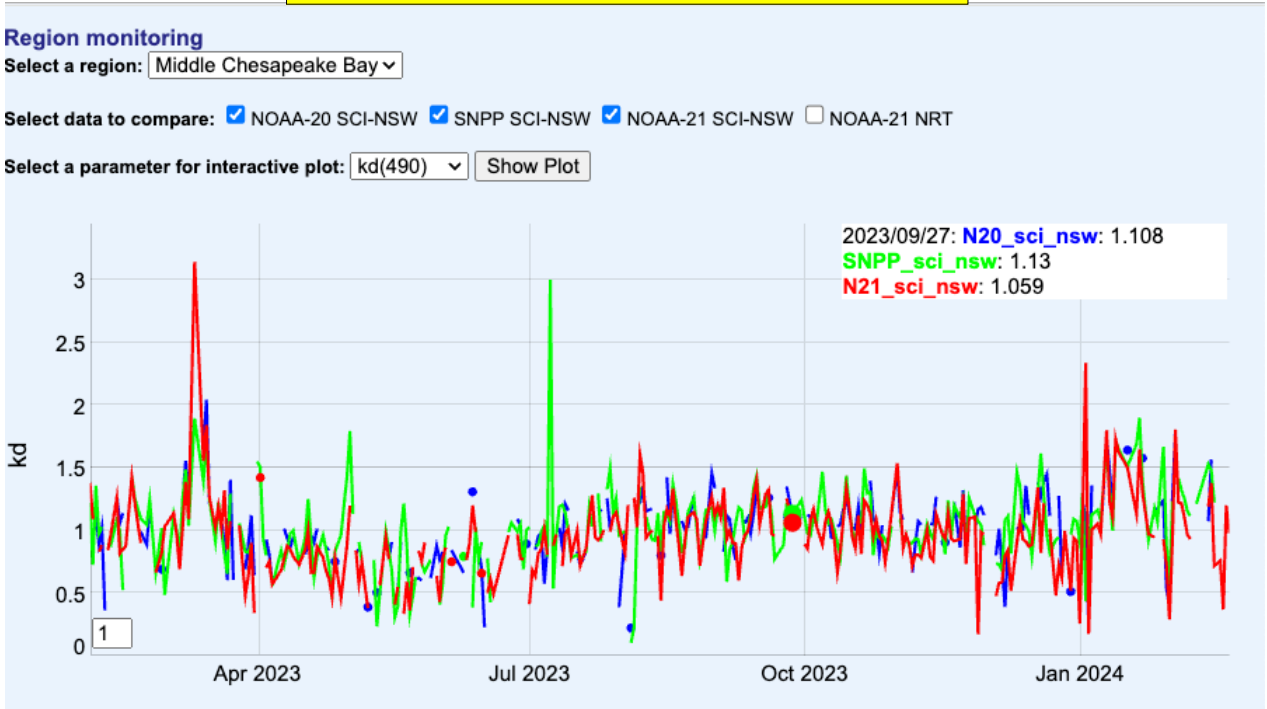
Over Mid Chesapeake Bay, Chl-a are differed ~0.823 mg/m^3 or ~5% (NOAA-21 vs. NOAA-20)

K_d(490) Comparisons (NOAA-21, NOAA-20, SNPP)

Regional: US East Coast



Regional: Mid Chesapeake Bay



Over US East Coast, K_d(490) are mostly **same** (NOAA-21 vs. NOAA-20)

Over Mid Chesapeake Bay, K_d(490) are differed by ~ <5% (NOAA-21 vs. NOAA-20)

Blue nL_w(M2) Statistics: Accuracy and Precision
(NOAA-21 Compared with NOAA-20)

Accuracy: Mean and Median of **Blue nL_w(M2)** NOAA-21/NOAA-20 Ratio

Dates	Global Oligotrophic Waters		Global Deep Waters		Coastal Waters Mid Chesapeake Bay	
Parameter (Requirement)	**Mean** (5%)	**Median** (5%)	**Mean** (5%)	**Median** (5%)	**Mean** (N/A)	**Median** (N/A)
From Feb 2023	**0.9627**	**0.9632**	**0.9574**	**0.9559**	1.0368	1.0187

Precision: Standard Deviation (STD) of **Blue nL_w(M2)** NOAA-21/NOAA-20 Ratio

Dates	Global Oligotrophic Waters	Global Deep Waters	Coastal Waters Mid Chesapeake Bay
Parameter (Requirement)	**STD** (5%)	**STD** (5%)	**STD** (N/A)
From Feb 2023	**0.0082**	**0.0107**	0.3036

VIIRS-NOAA-21 Blue nL_w(M2) Meets the Requirements (DPS-90 & 93)!

Chl-a Statistics: Accuracy and Precision
(NOAA-21 Compared with NOAA-20)

Accuracy: Mean and Median of **Chl-a** NOAA-21/NOAA-20 Ratio

Dates	Global Oligotrophic Waters		Global Deep Waters		Coastal Waters Mid Chesapeake Bay	
Parameter (Requirement)	**Mean** (30%)	**Median** (30%)	**Mean** (30%)	**Median** (30%)	**Mean** (N/A)	**Median** (N/A)
From Feb 2023	**1.1820**	**1.1907**	**1.1810**	**1.1927**	1.0807	1.0032

Precision: Standard Deviation (STD) of **Chl-a** NOAA-21/NOAA-20 Ratio

Dates	Global Oligotrophic Waters	Global Deep Waters	Coastal Waters Mid Chesapeake Bay
Parameter (Requirement)	**STD** (30%)	**STD** (30%)	**STD** (N/A)
From Feb 2023	**0.0694**	**0.0653**	0.4877

VIIRS-NOAA-21 Chl-a Meets the Requirements (DPS-91 & 95)!

Requirement Check List – Ocean Color/Chlorophyll

DPS	Requirement	Performance
DPS-88	The Ocean Color/Chlorophyll product shall provide ocean color (normalized water-leaving radiance nLw) and chlorophyll-a concentration; for ocean, coastal, or inland water; daytime; in clear conditions; at the refresh rate of the instrument.	**Yes**
DPS-90	The Ocean Color/Chlorophyll product shall provide ocean color (normalized water-leaving radiance nLw) over open oceans and at blue band (443 nm) with a measurement precision of 5% (science quality data), over the measurement range of the instrument.	**Yes** (< ~1%)
DPS-91	The Ocean Color/Chlorophyll product shall provide chlorophyll-a concentration over open oceans with a measurement precision of 30% (science quality data), over the measurement range of the instrument.	**Yes** (< ~7%)
DPS-93	The Ocean Color/Chlorophyll product shall provide ocean color (normalized water-leaving radiance nLw) over open oceans and at blue band (443 nm) with a measurement accuracy of 5% (science quality data).	**Yes** (< ~5%)
DPS-94	The Ocean Color/Chlorophyll product shall demonstrate that over open oceans errors in normalized water-leaving radiance nLw are spectrally correlated in the contributing sensor bands.	**Yes** (Errors strongly correlated R^2 of 0.99 in logscale)
DPS-95	The Ocean Color/Chlorophyll product shall provide chlorophyll-a concentration over open oceans with a measurement accuracy of 30% (science quality data).	**Yes** (< ~19%)

Check List - Provisional Maturity

Provisional Maturity End State	Assessment
Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from select locations, periods, and associated ground truth or field campaign efforts.	**Yes**---OC products have been extensively evaluated using MOBY in situ data (limited data number) and AERONET-OC sites, as well as VIIRS-NOAA-20/SNPP global and regional ocean color data, showing reasonable quality data from Feb. 2023.
Product analysis is sufficient to communicate product performance to users relative to expectations (Performance Baseline).	**Yes**---Quantitative evaluation results from in situ and satellite measurements are provided.
Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, tested, and shared with the user community.	**Yes**----Going forward plan is provided. VIIRS-NOAA-21 will produce the same data quality as VIIRS-NOAA-20/SNPP.
Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.	**Yes**---For VIIRS data from Feb. 2023.

Documentations (Check List, 1 slide)

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes
(External/Internal) Users Manual	Yes
System Maintenance Manual (for ESPC products)	—
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	Yes

User Feedback

Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations
Sherwin Ladner	Naval Research Lab	Validation of Navy Operational models; Oceanography research	Fully meets Navy/NRL quality requirements as presented at OC EDR VIIRS Cal/Val team telecon.
Jianke Li, Andrew LaRoy	MAXAR	Fishing efficiency – commercial product	Downloading NOAA-20 NRT L2 daily now; they are active user and contact CW helpdesk if any data are late or missing.
CW HelpDesk Inquirer	A notable international research institution	Unknown – not disclosed but region of interest was a moderate-sized (with respect to pixel resolution) inland lake	Found OC team website and OCView useful; received valuable help subsetting and downloading VIIRS OC files of interest.

Some known users of VIIRS OC from CoastWatch

User Feedback

Organization	User Feedback
EUMETSAT	Use the NOAA-20 OC products operationally
OAR AOML	Will use the NOAA-20 OC products to derive marine gas and aerosol emissions to support NWS National Air Quality Forecast Capability (NAQFC) operations
NCEP EMC	EMC marine group plan to use Global granules for Chl-a, Rrs, K490, Kpar and Chl-a fronts
NOS HAB/COOP	Will use the NOAA-20 OC products for Harmful Algal Bloom (HAB) operational forecast analysis after MODIS/Aqua mission ends
RipCharts LLC	Will use the data to analyze fisheries information, provide fishing intelligence to commercial/recreational anglers, and marine biology analysis
CSDsolution LLC	conducting research practical applications of a number of ocean color products
Roffer's Ocean Fishing Forecasting Service (ROFFS)	Will use the products for day-to-day monitoring the ocean conditions to support NOAA fisheries research activities and research projects

Some known users

User Feedback

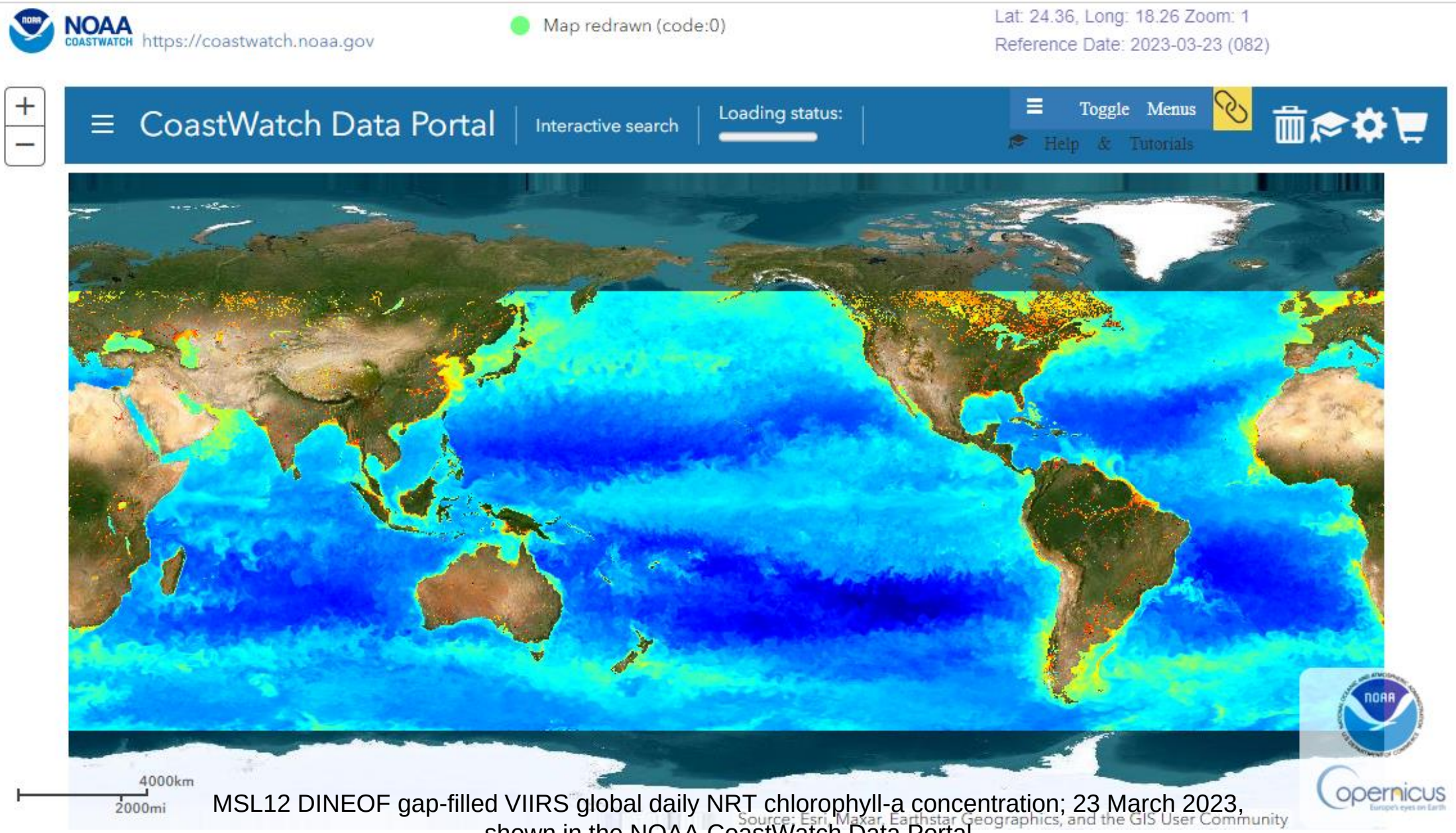
Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations
Cara Wilson, Dale Robinson	NOAA CoastWatch West Coast Node (**NMFS/SWFSC**)	NMFS/SWFSC sardine habitat model	Transitioning the SWFSC sardine habitat model to use input from newer generation NOAA satellite products (e.g. VIIRS chlorophyll, VIIRS SST, and Blended Geopolar SST).
Cara Wilson, Dale Robinson	NOAA CoastWatch West Coast Node (**NMFS/SWFSC**)	NMFS/SWFSC California Harmful Algae Risk Mapping (C-HARM) harmful algal bloom (HAB) model	The C-HARM HABs products will switch to using either NOAA-20 or SNNP/NOAA-20 blended some time in the next FY.
Cara Wilson, Dale Robinson	NOAA CoastWatch West Coast Node (**NMFS/SWFSC**)	Other comments from West Coast Node	The products are relatively new. We have introduced a lot of people to them, but it will take some time before our users start using them. Most have just switched to SNPP (many with JPSS funding) so switching again won't happen for a while. Others will need a reason to switch if SNPP is working fine. Switching over takes a resource commitment. I will say that every user I've talked to is excited about the blended SNPP/NOAA-20 product.

NOAA CoastWatch Node Users and Downstream Applications (1 of 2)

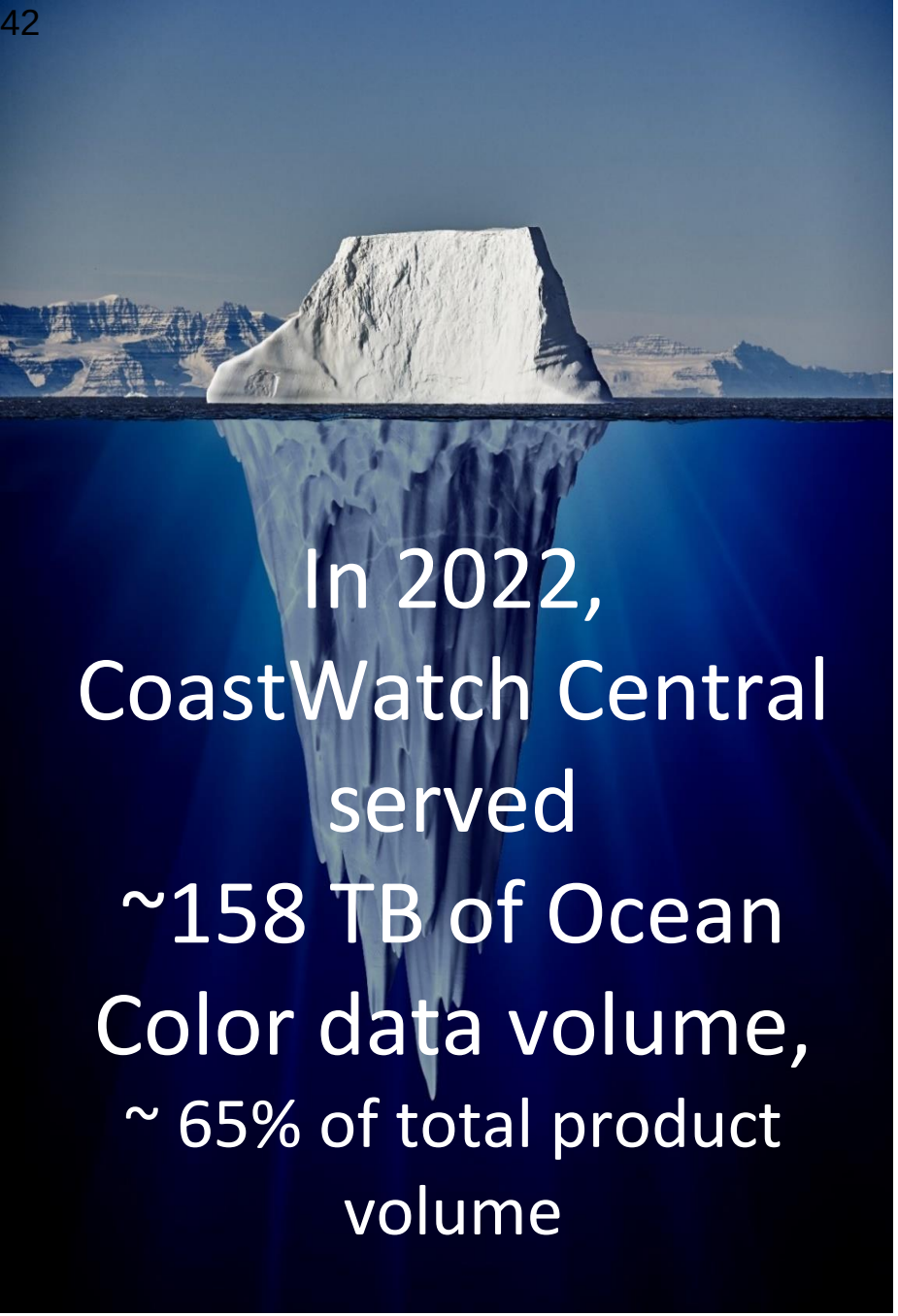
User Feedback

Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations
Gustavo Goni, Joaquin Trinanes	NOAA CoastWatch – Gulf of Mexico, Caribbean and Atlantic OceanWatch Node (**OAR/AOML**)	Modeling ocean carbon fluxes (e.g., CO_2, ocean acidification monitoring)	Model running routine, experimentally now, evaluating results, neural network has been trained using different datasets, including chlor data from VIIRS; **Collaborator and downstream user, Rik Wanninkhoff (OAR/AOML);** *potential downstream users of the model in Ocean Acidification Program (Dwight Gledhill; OAR/OAP)***.**
Gustavo Goni, Joaquin Trinanes	NOAA CoastWatch – Gulf of Mexico, Caribbean and Atlantic OceanWatch Node (**OAR/AOML**)	CoastWatch (AOML) Hurricane OceanViewer	Currently includes multi-day chlor-a composite products from VIIRS, which are used as a proxy to locate low salinity areas, using the surface chlorophyll conditions to track the location of the Amazon and Orinoco plumes. **Downstream user is OAR/AOML Hurricane Research Division** *and National Hurricane Center forecasts ultimately benefit from research.*

NOAA CoastWatch Node Users and Downstream Applications (2 of 2)



MSL12 DINEOF gap-filled VIIRS global daily NRT chlorophyll-a concentration; 23 March 2023, shown in the NOAA CoastWatch Data Portal



In 2022, CoastWatch Central served ~158 TB of Ocean Color data volume, ~ 65% of total product volume

- HelpDesk
- Training
- Forum
- Email / Newsletter Subscription

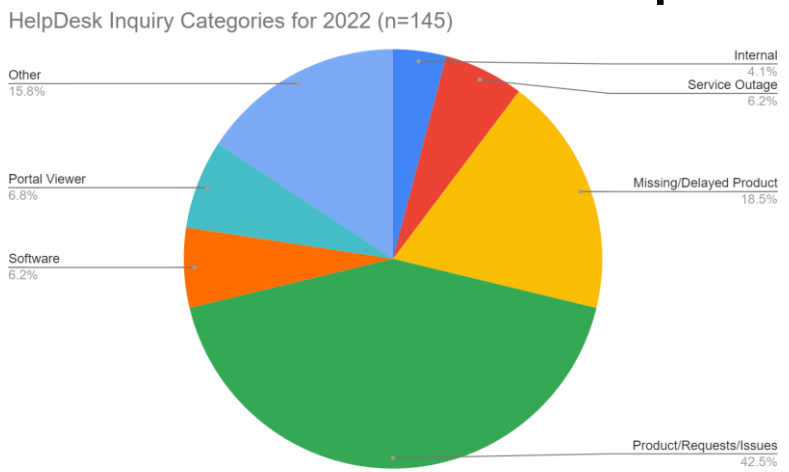
Known Users

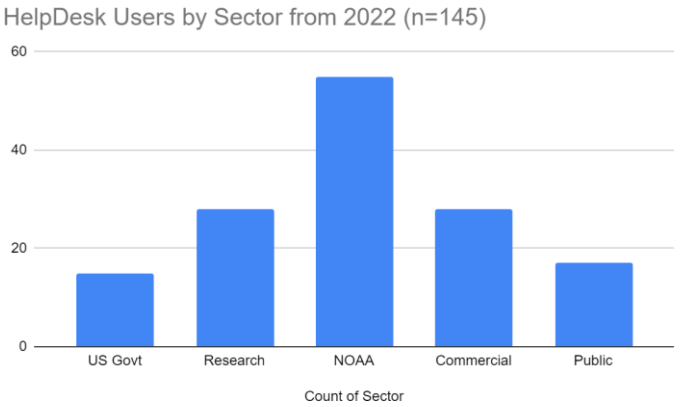
Unidentified Users

Issues / Outages

- Web Analytics
- Log Analysis

2022 Help Desk Statistics



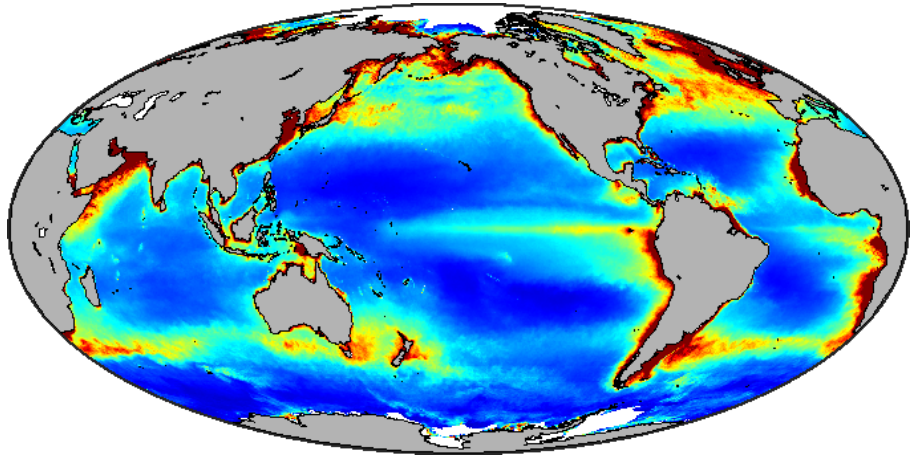


CoastWatch HelpDesk: CoastWatch.Info@NOAA.gov
Online public user forum: https://vlab.ncep.noaa.gov/web/coastwatch

The NOAA Fisheries User Need and Impact

- An essential variable

  NetPP and Chlorophyll-a are to Biological Oceanography what Temperature and Salinity are to Physical Oceanography. The biological components are complex and a function of non-conservative elements (nutrients).



Annual average NPP from VGPM model (mg Carbon m^{-2} day^{-1})

- Data continuity requirement

  There is a general lack of long-term biological satellite data (compared to physical parameters like SST), especially in the marine environment. To fully understand the complex marine/aquatic ecosystems (and the changes within), both the physical and foundational biological parameters are needed. Long-term (consistent) records are required to understand impacts of climate change.

- Climate data record quality inputs are a critical component

  In several validation studies, >⅓ of uncertainty in NetPP models are attributed to uncertainties in inputs.

UN Environment Sustainable Development Goal: Coastal Eutrophication Indicators

Indicator 14.1.1

Index of coastal eutrophication and floating plastic debris density

14 LIFE BELOW WATER

UN environment programme

- **14.1.1a:** Index of Coastal Eutrophication (ICEP)

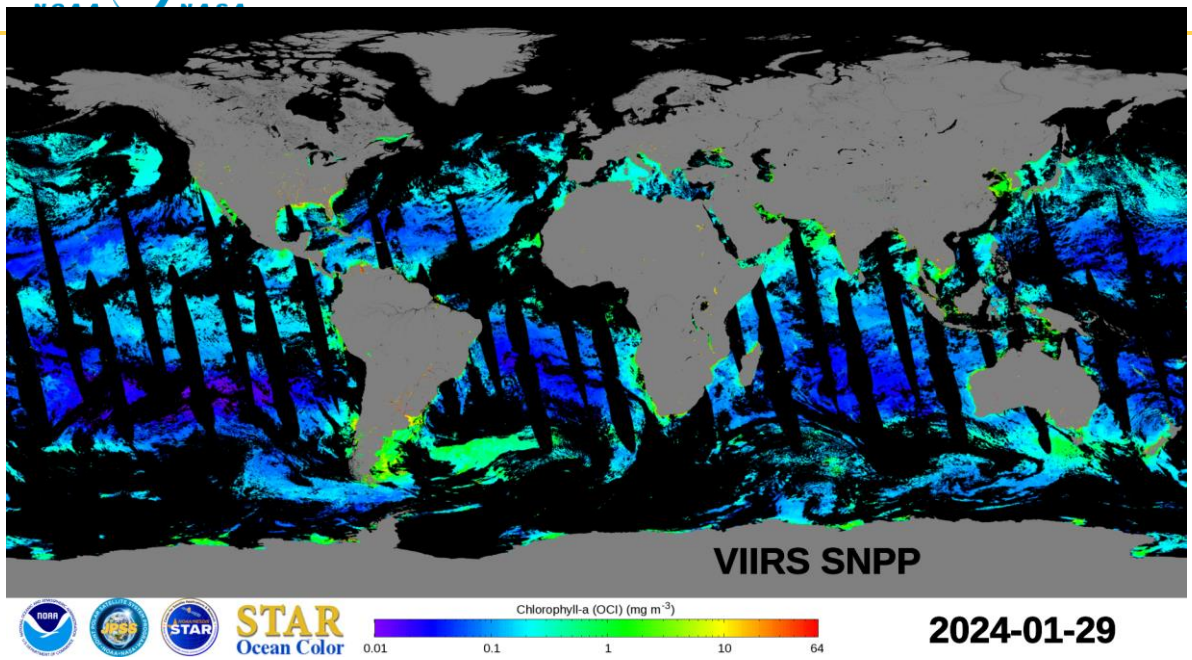
1. **Percentage of coastal zone with Chl-a deviations**
   - ESA Ocean Colour CCI (OC_CCI) product, led by the Plymouth Marine Laboratory (PML): consistent, merged chlorophyll-a product from SeaWiFS, MODIS, MERIS and VIIRS, spanning 1997 to 2018.

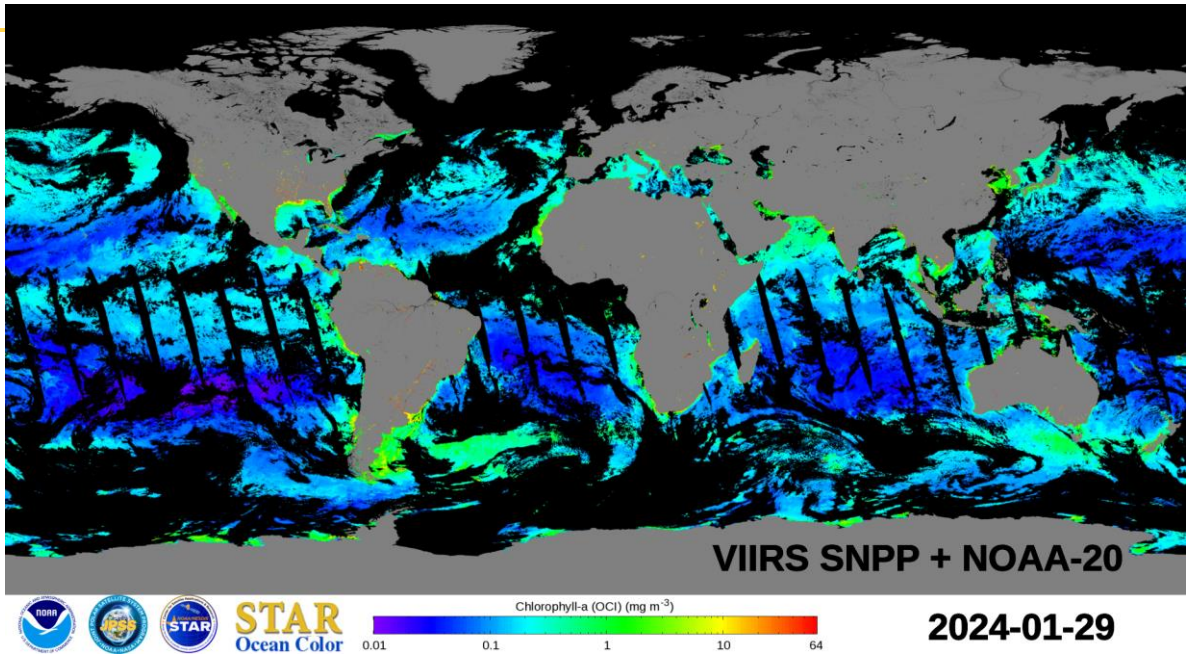
2. **Intra-annual coastal zone chloryphyll-A anomalies**
   - NOAA VIIRS chlorophyll-a anomaly products: 1) the difference anomaly and 2) the anomaly ratio, both calculated using a running 61-day Chl-a median.

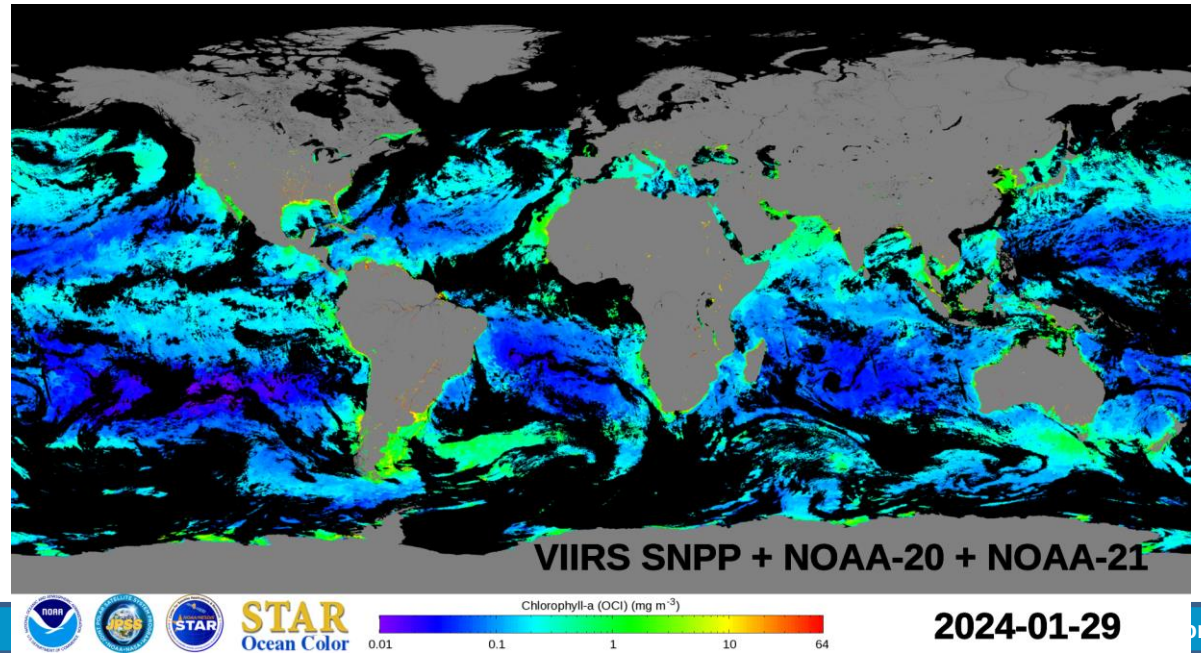
GEO BLUE PLANET

Example Water Balance Application/Dashboard

Potential Benefits of 3 JPSS Satellites (1 slide)





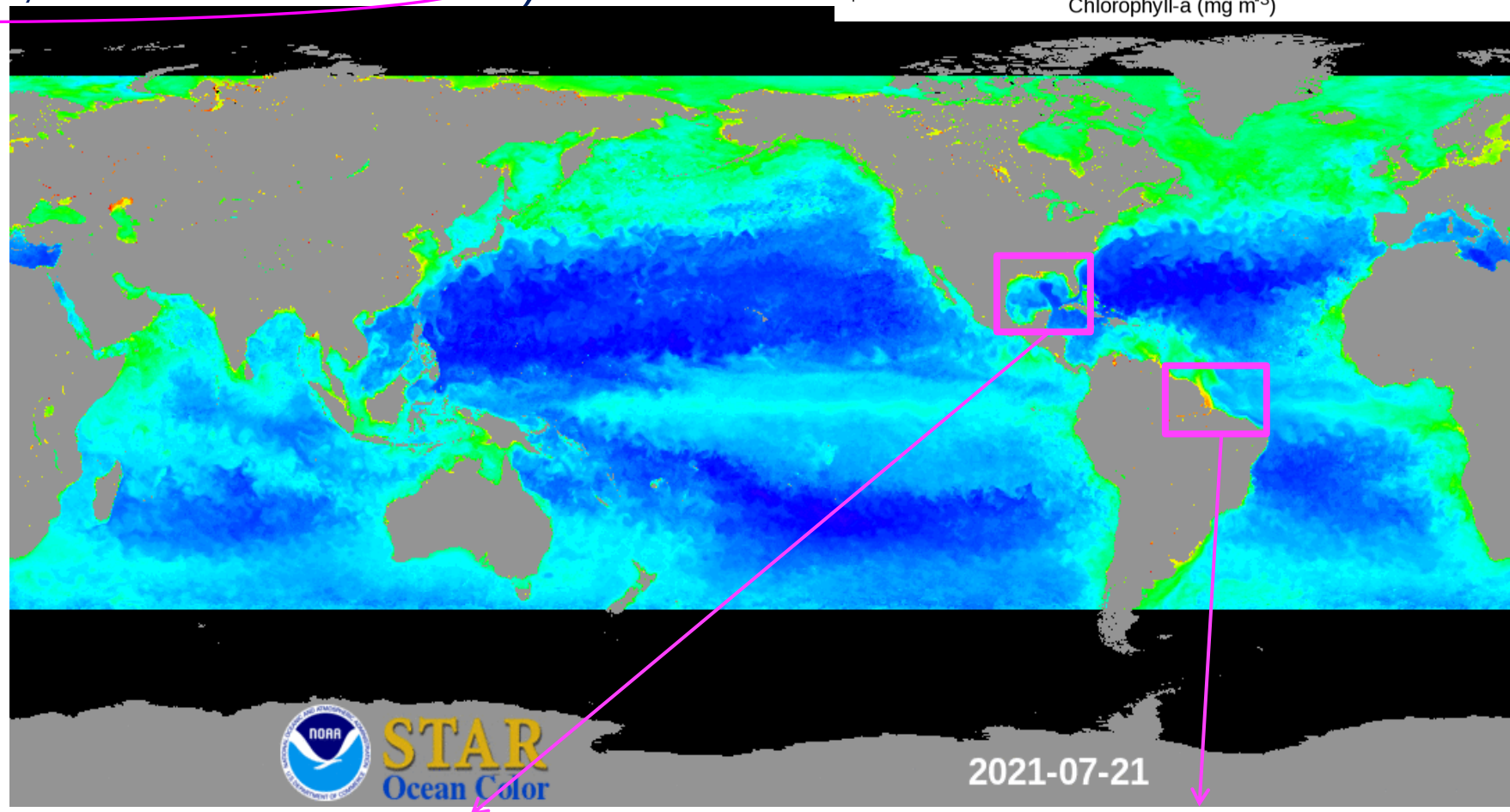


- What would be values and benefits for the products to keep three JPSS satellites on orbit (NOAA-21 NOAA-20, and SNPP):
  Complete daily OC data coverage (examples **gap-free da**ta next)
- Application examples (sun glint, cloud free condition, possible science exploration…):
  No data gaps due to sun glint and large sensor angles, reduced data gaps from clouds (**gap-free** data next)

Three-Sensor Global Gap-Free Chl-a Data

(VIIRS-SNPP, VIIRS-NOAA-20, and OLCI-Sentinel-3A)

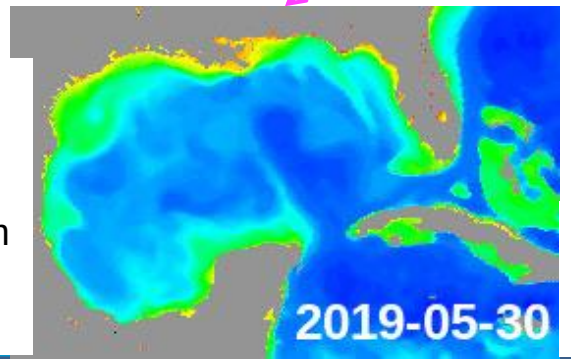
- **Three-sensor** (VIIRS-SNPP, VIIRS-NOAA-20, and OLCI-S3A) global data are merged to produce improved data coverage.
- The Data Interpolating Empirical Orthogonal Function (**DINEOF**) is used to producing global daily gap-free products.
- Routinely global daily gap-free Chl-a, $K_d(490)$, and SPM products and images (in both 2- and 9-km).
- Gap-free products are distributed through NOAA CoastWatch.



Meso-scale ocean features in the gap-free Chl-a data (two examples shown in the right)

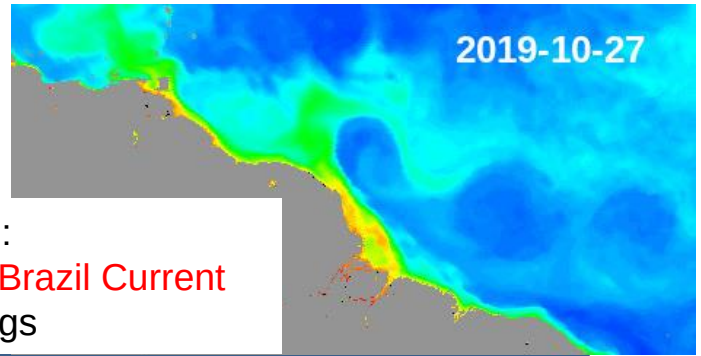
In the movie:

- Formation of Loop Current Eddy (LCE): a LCE shedding from the Loop Current around 7/10/2019



In the movie:

- Northern Brazil Current (NBC) rings



Summary

- The mission-long VIIRS-NOAA-21 OC products have been reprocessed using the new gains derived from MOBY in situ data. The NOAA-21 OC data are being routinely produced and monitored using various in situ data, as well as several satellite data.
- We have extensively evaluated VIIRS-NOAA-21 ocean color data using MOBY and AERONET-OC in situ data, as well as regional and global data from VIIRS-NOAA-20/SNPP.
- Results show that, from Feb. 2023, VIIRS-NOAA-21-derived ocean color data generally agree well with in situ data and global VIIRS-NOAA-20/SNPP measurements. The NOAA-21 ocean color data quality is high and meet the data quality (accuracy and precision) requirements.
- However, over global open oceans some small biases/differences in OC data are observed, compared with those from SNPP and NOAA-20. This will require further efforts to understand and correct these differences. Some regional comparison results show consistent OC results from three VIIRS (SNPP, NOAA-20, and NOAA-21).
- **Based on the definition and the evidence shown in the presentation, VIIRS-NOAA-21 ocean color products (from Feb. 2023) have met the Provisional stage and are ready for operational evaluation.** It should be noted that further improvement in both SDR and EDR are needed, particularly for coastal/inland waters.

Path Forward

- Continue to produce consistent VIIRS SNPP and NOAA-20 OC products and will work on NOAA-21 OC data consistency with other two VIIRS sensors.
- We will start to **reprocess** the mission-long SNPP ocean color data using the new MSL12 data processing system.
- After the SNPP OC data reprocessing, we will have to start the mission-long NOAA-20 OC data reprocessing. Therefore, the same version MSL12 are used and can be applied to all three VIIRS (SNPP, NOAA-20, and NOAA-21).
- MOBY in situ data: The MOBY team will generate more MOBY in situ data using refresh/new MOBY instrument. We will work with the MOBY team for utilizing new MOBY in situ data for VIIRS vicarious calibration, as well as satellite OC data monitoring and evaluations (from VIIRS and other sensors, e.g., OLCI, SGLI, etc.).
- Improvement of the OCView tool for satellite OC products monitoring and displaying.
- The OC Cal/Val team will complete the 2022 VIIRS dedicated cruise (over Hawaii region) report and in situ data analyses.
- The OC Cal/Val team will conduct the 2024 VIIRS dedicated cruise (the 9th) in the spring 2024. These dedicated cruise in situ data will be used for VIIRS and new PACE ocean color data validation.
- More in situ data are needed and will be provided from the VIIRS Cal/Val team.
- We will continue working on (improving) in situ data quality (instrument calibration, measurement protocols, data processing methodology, etc.)
- Continue working on sensor on-orbit calibration, algorithms improvements, etc.
- Continue working on algorithms improvements in MSL12 for both open oceans and particularly coastal/inland waters.
- Continue working on VIIRS ocean color data applications for users (connecting users for VIIRS OC data).