Validated Maturity Science Review For NOAA-20 Ocean Color Algorithm

Presented by *Menghua Wang*

Date: *2020/07/17*

JPSS Data Products Maturity Definition

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-20 OCEAN COLOR—VALIDATED 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, 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
- Risks, Actions, and Mitigations
- Documentation (Science Maturity Check List)
- Path Forward
- Conclusion

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, S. Son, L. Tan, X. Wang, J. Wei, **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**, Robert Arnone	NRL	JPSS/NJO	Ocean color data validation, Cruise participation and support, WAVE_CIS (AERONET-OC site) operation
	Nicholas Tufillaro, Curt Davis	OSU	JPSS/NJO	Ocean color validation, Cruise data matchup West Coast
	Matthew Ragan, Burt Jones	USC	JPSS/NJO	Eureka (AERONET-OC Site)
	Alex Gilerson, Sam Ahmed	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)
	Zhongping Lee	UMB	JPSS/NJO	Ocean color IOP data validation and evaluation Ocean color optics matchup

Working with: **NOAA CoastWatch**, VIIRS SDR team, DPA/DPE, Raytheon, NOAA OC Working Group, NOAA various line-office reps, NOAA NCEI, NOAA OCPOP, IOCCG, NASA, ESA, EUMETSAT, etc.

Collaborators: D. Antoine (BOUSSOLE), B. Holben (NASA-GSFC), G. Zibordi (JRC-Italy), 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 (BMW–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 and NOAA-20), OLCI/Stentinel-3, GOCI, and will also add J2 and SGLI/GCOM-C data processing capability.

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		

Data Format:
NetCDF4 output for MSL12

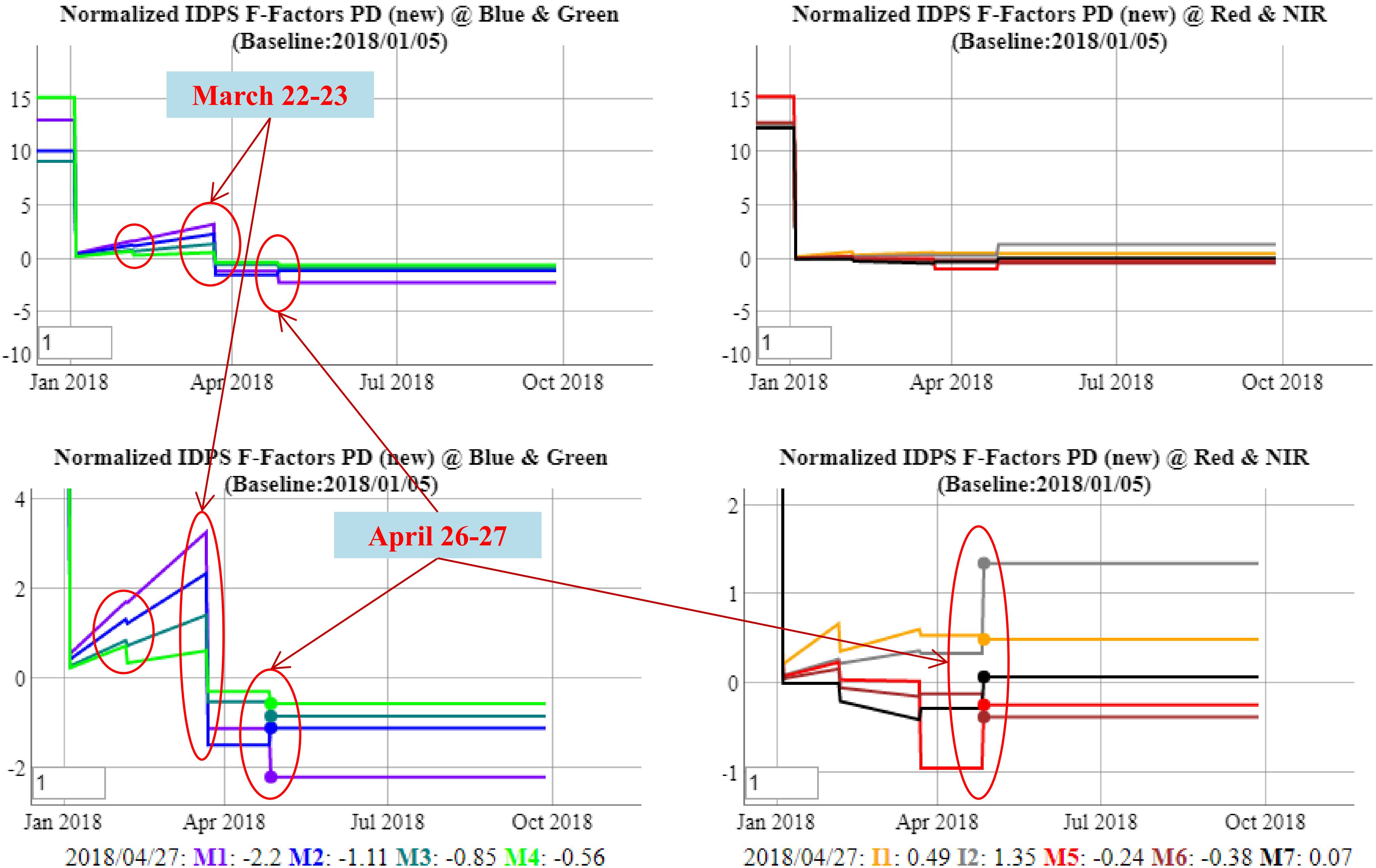
- MSL12 produces Level-2 file (EDR) in NetCDF4 format for VIIRS-SNPP and VIIRS-NOAA-20.
- The NetCDF4 output is defaulted to be chunked and compressed with deflate Level-1B (SDR), with file size reduced to about 1/4 of the uncompressed size.
- The NetCDF4 output is compliant with NetCDF Climate and Forecast (CF) conventions as well as conventions for Unidata Dataset Discovery.
- All post-process programs have been modified to be compatible with both HDF4 and NetCDF4 Level-2 files.

Summary of VIIRS Ocean Color EDR Products (Updates-Based on Users Input)

- **Inputs**:
  - VIIRS M1-M7, I1, and the **SWIR** M8, M10, and M11 bands SDR data
  - Terrain-corrected geo-location file
  - Ancillary meteorology and ozone data
- **Operational (Standard) Products** (10):
  - Normalized water-leaving radiance (nL_w's) at VIIRS visible bands M1-M5, and **I1 (638 nm)**
  - Chlorophyll-a (Chl-a) concentration
  - Diffuse attenuation coefficient for the downwelling spectral irradiance at the wavelength of 490 nm, $K_d(490)$
  - Diffuse attenuation coefficient of the downwelling photosynthetically available radiation (PAR), K_d(PAR)
  - **QA Score** for data quality ($nL_w(\lambda)$ spectra) (*Wei et al.*, 2016)
  - Level-2 quality flags
- **Experimental Products (29):**
  - Inherent Optical Properties (IOP-a, IOP-a_{ph}, IOP-a_{dg}, IOP-b_b, IOP-b_{bp}) at VIIRS M2 or other visible bands (M1-M5) from the Quasi-Analytical Algorithm (QAA) (*Lee et al.*, 2002), improved over coastal and inland waters (**Shi and Wang, 2019**).
  - Photosynthetically Available Radiation (PAR) (*R. Frouin*)
  - Chl-a from ocean color index (OCI) method (*Hu et al.*, 2012; *Wang and Son*, 2016)
  - Others, e.g., user specific products (e.g., **Chl-a anomaly** and **Chl-a anomaly ratio**)

➢ Data quality of ocean color EDR are extremely sensitive to the SDR quality. It requires **~0.1%** data accuracy (degradation, band-to-band accuracy…)!

NOAA-20 IDPS F-Factors



The last big change was on April 27, 2018 and there has been no change on the NOAA-20 calibration.

VIIRS-NOAA-20 IDPS SDR before April 27, 2018 has some data quality problems!

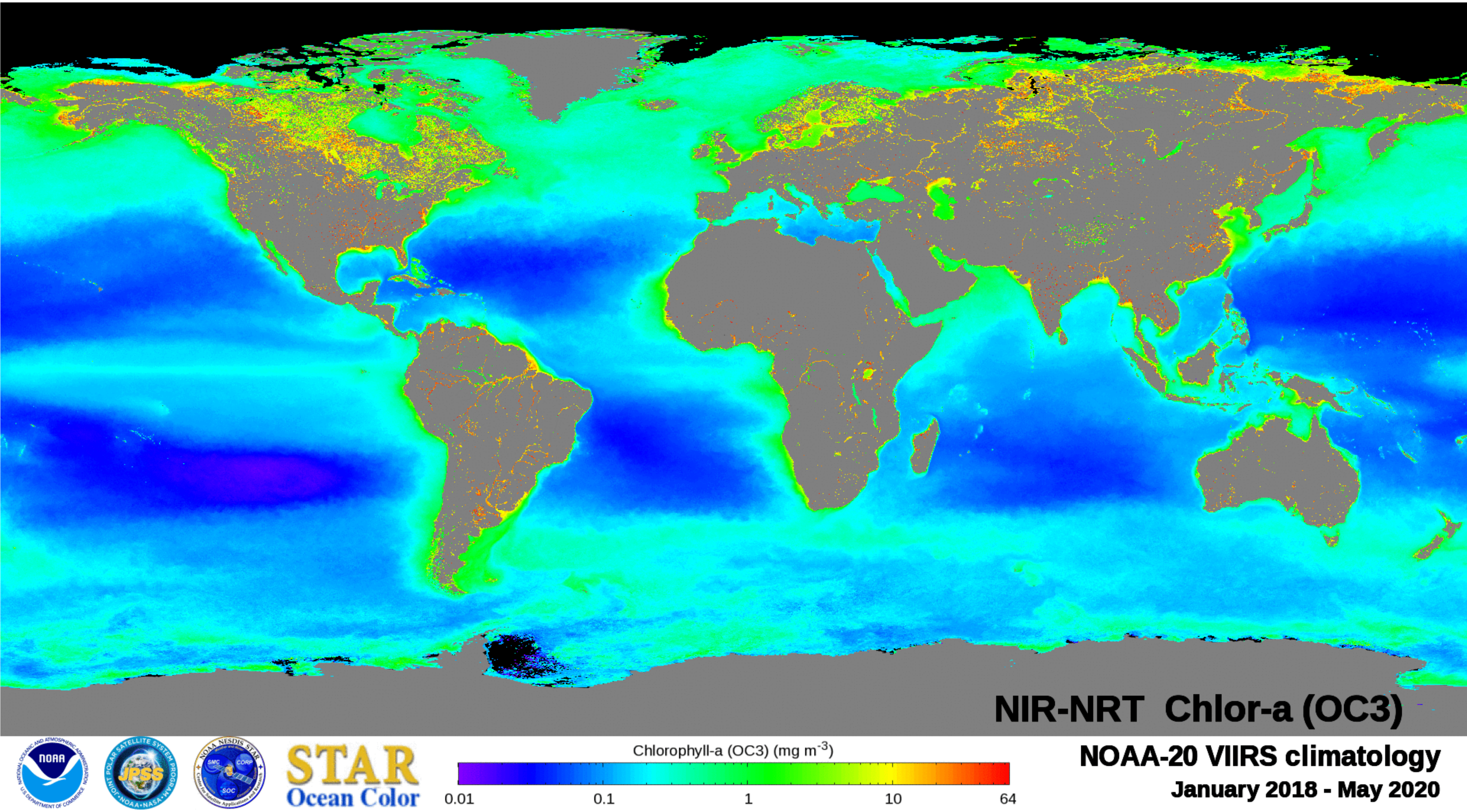
Menghua Wang, NOAA/NESDIS/STAR

Effort on Producing VIIRS-NOAA-20 Global Ocean Color Products

- The VIIRS Ocean Color EDR team has made significant effort on routinely producing VIIRS-NOAA-20 ocean color products. Initially, we had some difficulties and challenges for the task mainly due to two factors (different from SNPP): (1) some sensor calibration issues leading to some SDR problems and (2) lack of sufficient number of high quality MOBY in situ data during the VIIRS-NOAA-20 initial mission period.
- Due to the lack of high quality MOBY in situ data in the initial period, we are forced to vicariously calibrate VIIRS-NOAA-20 using the VIIRS-SNPP ocean color products (inter-sensor calibration) over the MOBY Hawaii site.
- Polarization correction algorithm for VIIRS-NOAA-20 has been implemented and shown significantly improved ocean color products (Sun et al., 2019).
- VIIRS-NOAA-20 near-real-time (NRT) global ocean color products have been routinely produced and distributed.
- In addition, two new global Chl-a data have been routinely produced and distributed (based on users feedback):
  - Merged global Chl-a data from VIIRS SNPP and NOAA-20.
  - Gap-free global Chl-a data derived from the merged global Chl-a data using the DINEOF method.

VIIRS Climatology Ocean Color Product Image

NOAA-20 (January 2018–May 2020)



MSL12 with the NRT data processing system is used for VIIRS

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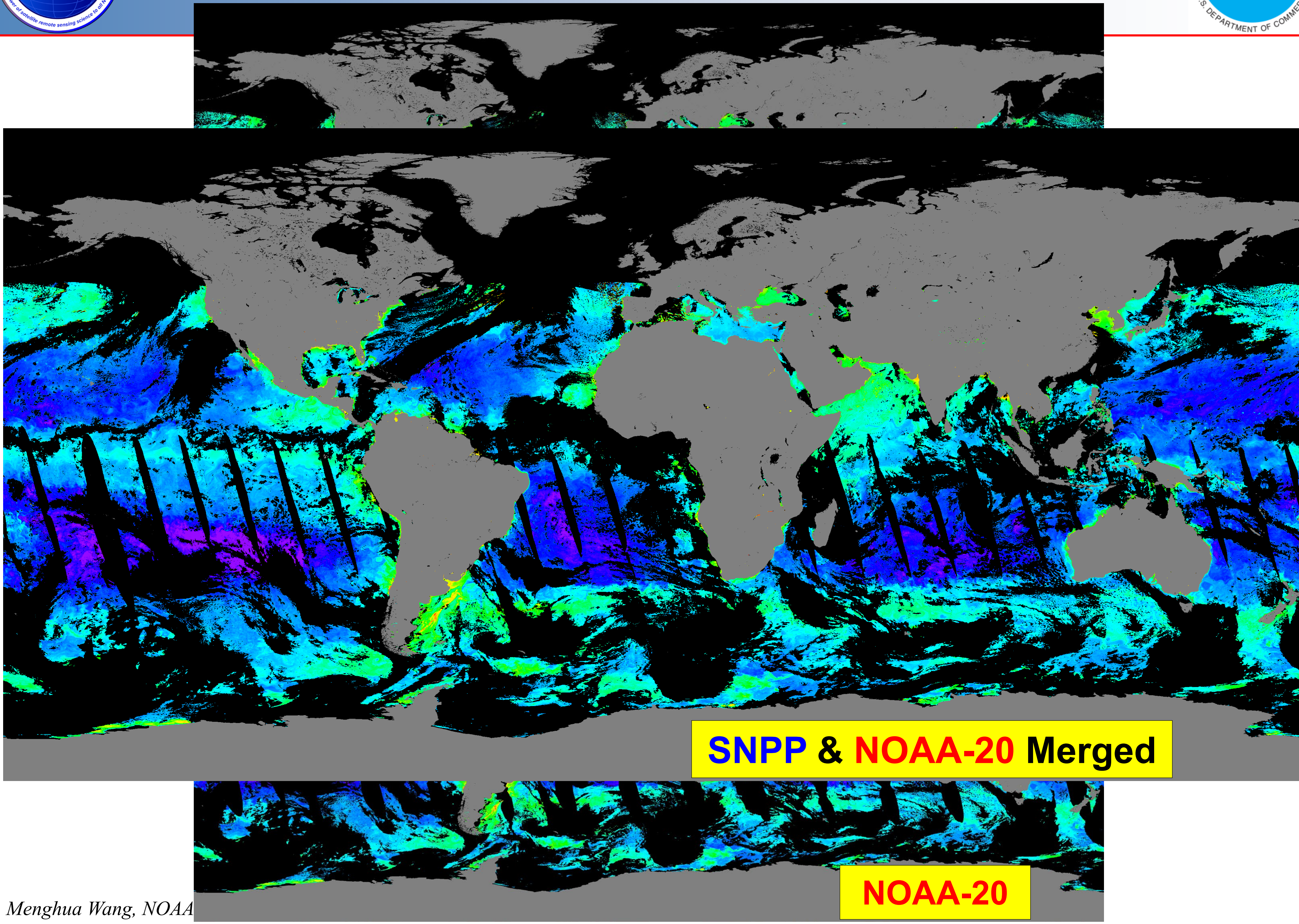
VIIRS-SNPP and NOAA-20 Chl-a Images

(January 6, 2018)

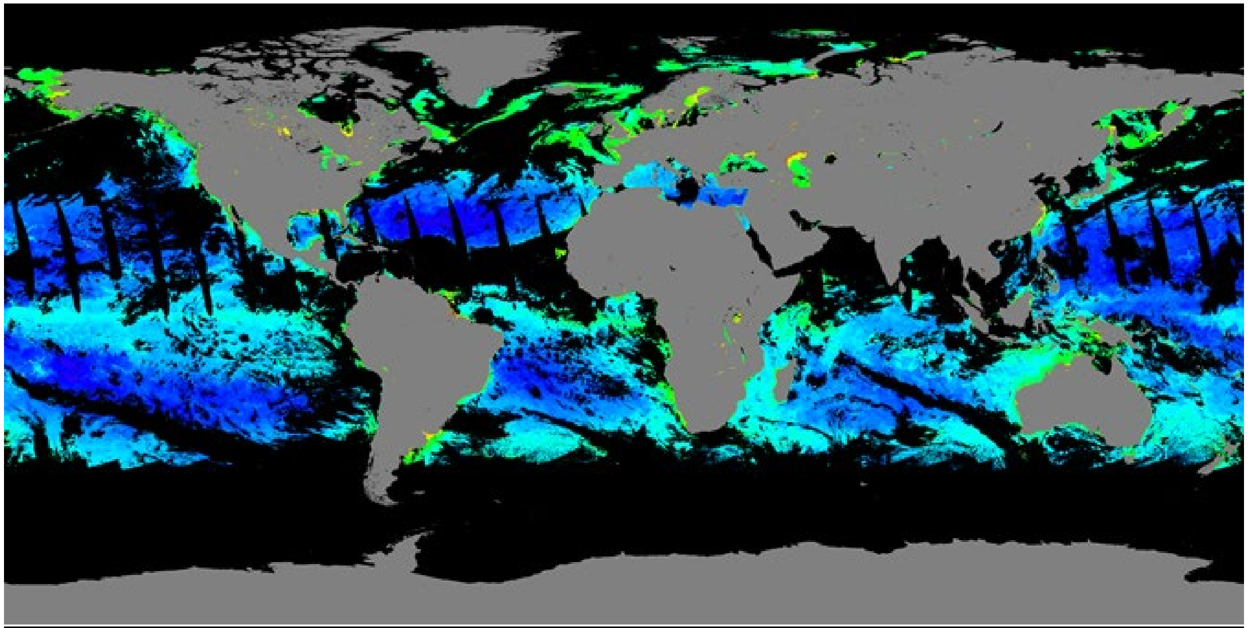


Menghua Wang, NOAA

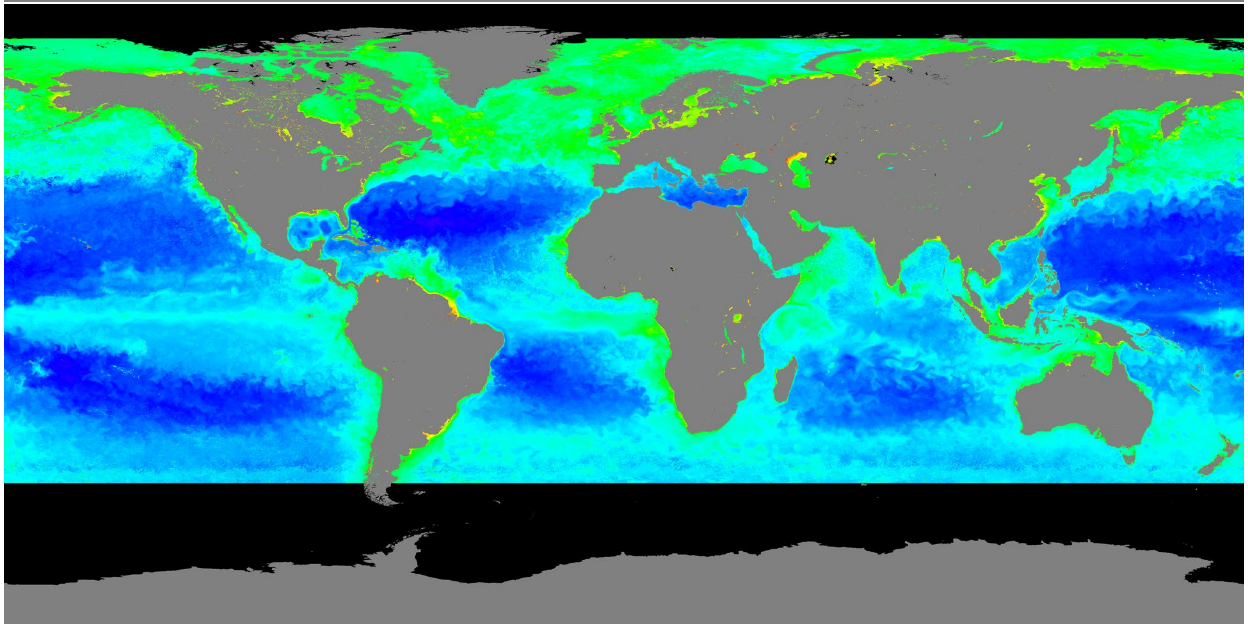
Example of Gap-free Chl-a Products

Global 9-km Chl-a Level-3 images (June 21, 2018)

Merged Product



Gap-free Product



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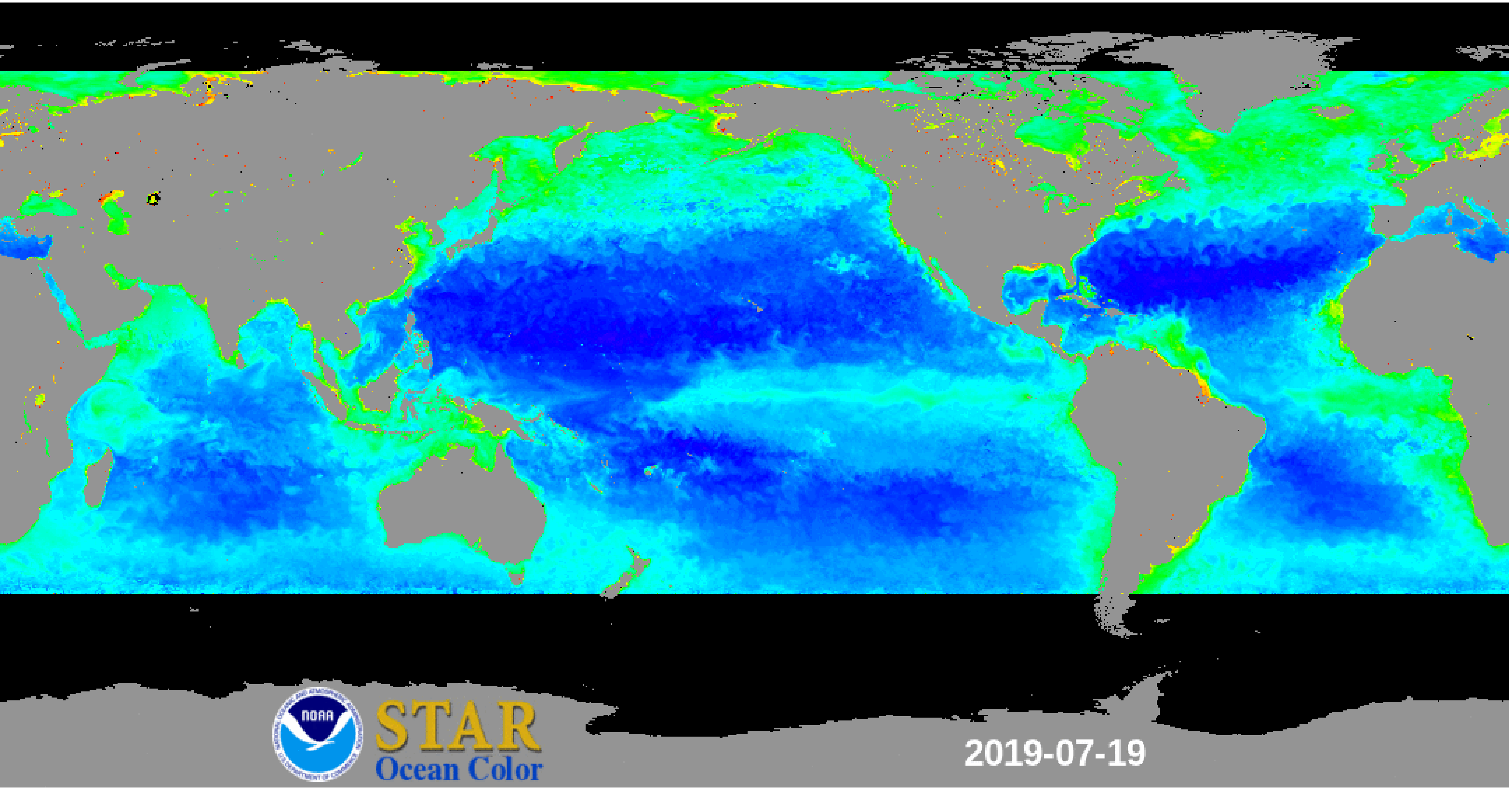
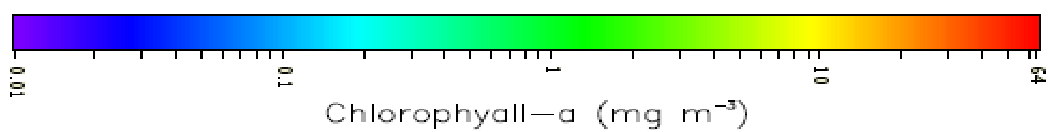
Gap-free Global Daily Chl-a Movie



MSL12 with the NIR-SWIR data processing system and the OCI Chl-a algorithm are used from VIIRS SNPP and NOAA-20 measurements



Gap-free daily global Chl-a data are now routinely produced and available through CoastWatch!

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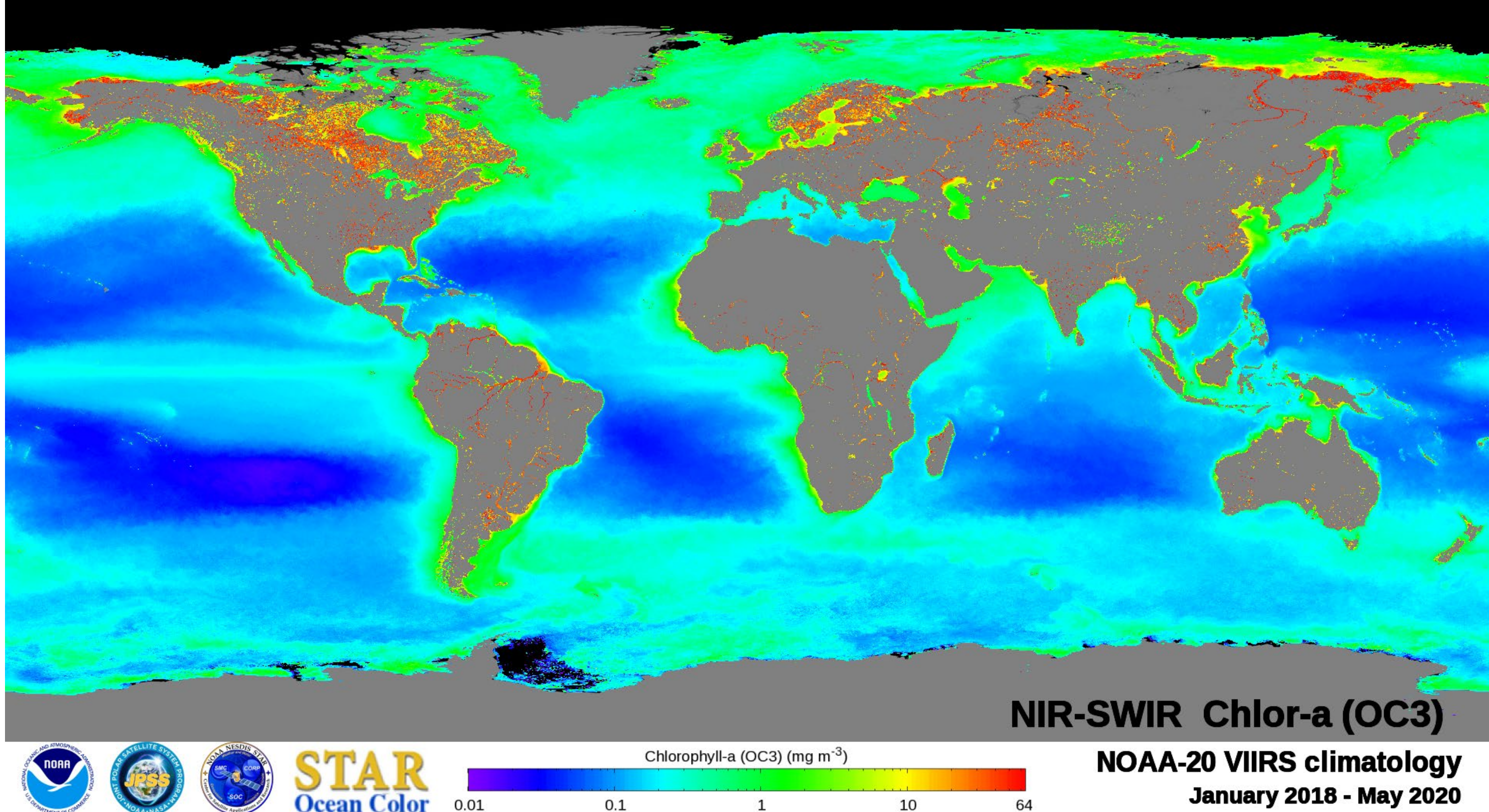
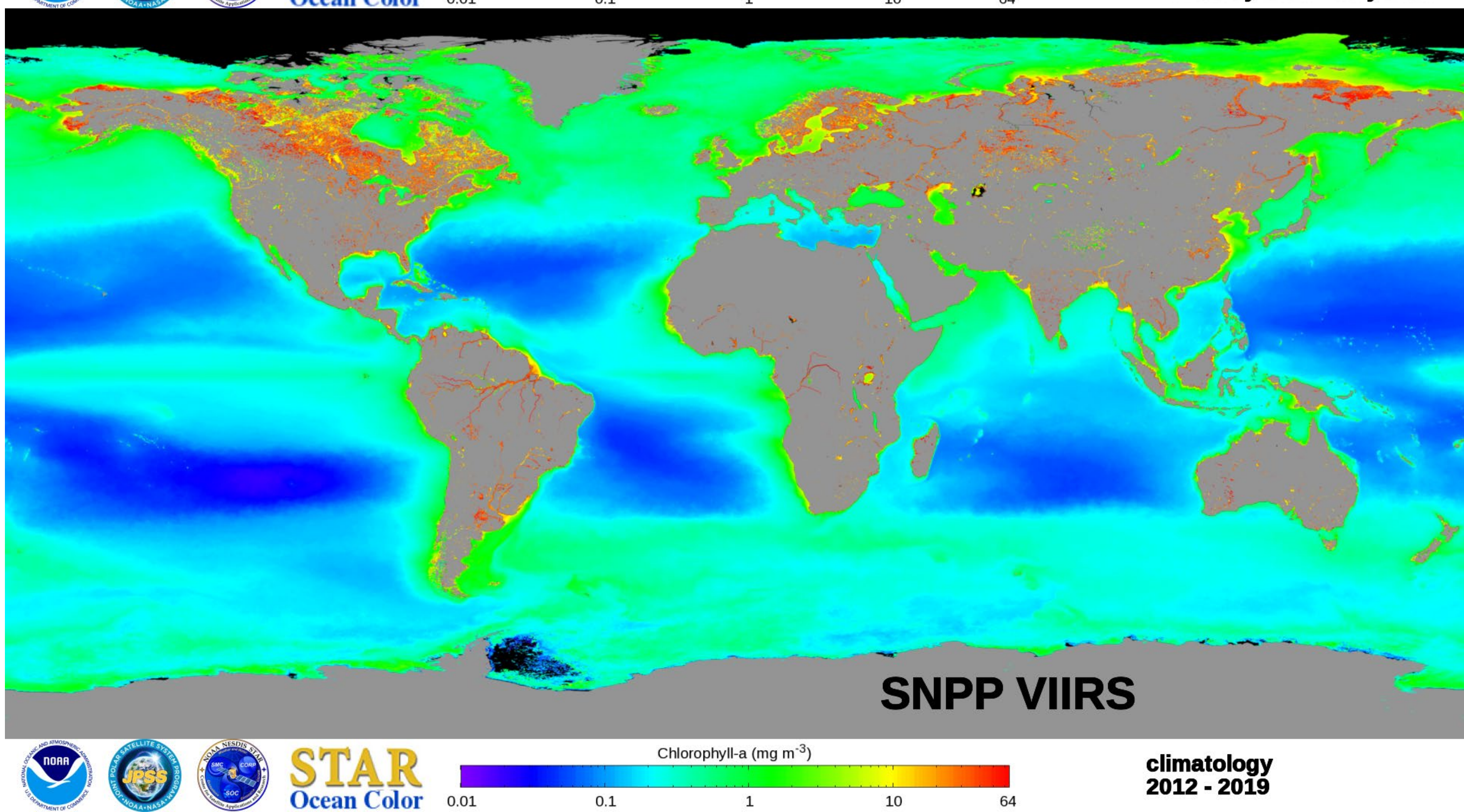
Climatology Chl-a from VIIR-NOAA-20 and VIIRS-SNPP





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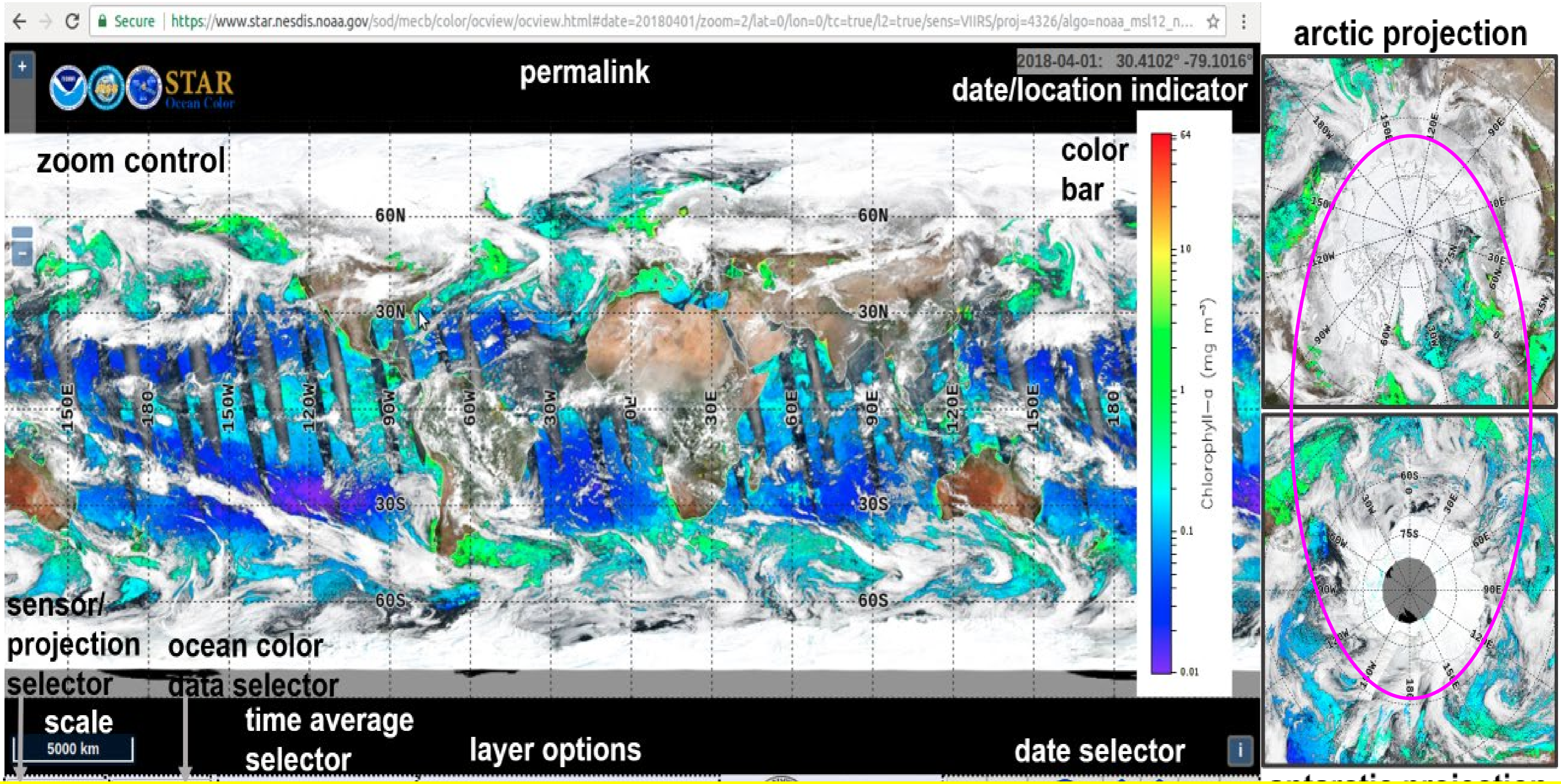
Ocean Color Viewer (OCView)



Mikelsons, K. and M. Wang, “Interactive online maps make satellite ocean data accessible” **Eos**, 99, 01 May 2018, https://doi.org/10.1029/2018EO096563.

http://www.star.nesdis.noaa.gov/sod/mecb/color/

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Requirement Check List – Ocean Color/Chlorophyll

JERD	Requirement	Performance
DPS-88	The Ocean Color/Chlorophyll product shall provide ocean color (nLw), chlorophyll-a, and optical properties; 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 with a measurement precision of 10%, over the measurement range of the instrument	
DPS-89	The Ocean Color/Chlorophyll product shall provide optical properties with a measurement precision of 20%, over the measurement range of the instrument	
DPS-91	The Ocean Color/Chlorophyll product shall provide chlorophyll-a density with a measurement precision of 30% below 10 mg/m^3, and 50% at and above 10 mg/m^3, over the measurement range of the instrument	
DPS-93	The Ocean Color/Chlorophyll product shall provide ocean color with a measurement accuracy of 10%	
DPS-94	The Ocean Color/Chlorophyll product shall provide optical properties with a measurement accuracy of 35%	
DPS-95	The Ocean Color/Chlorophyll product shall provide chlorophyll-a density with a measurement accuracy of 35% below 10 mg/m^3, and 40% at and above 10 mg/m^3	

Requirement Check List – Ocean Color/Chlorophyll

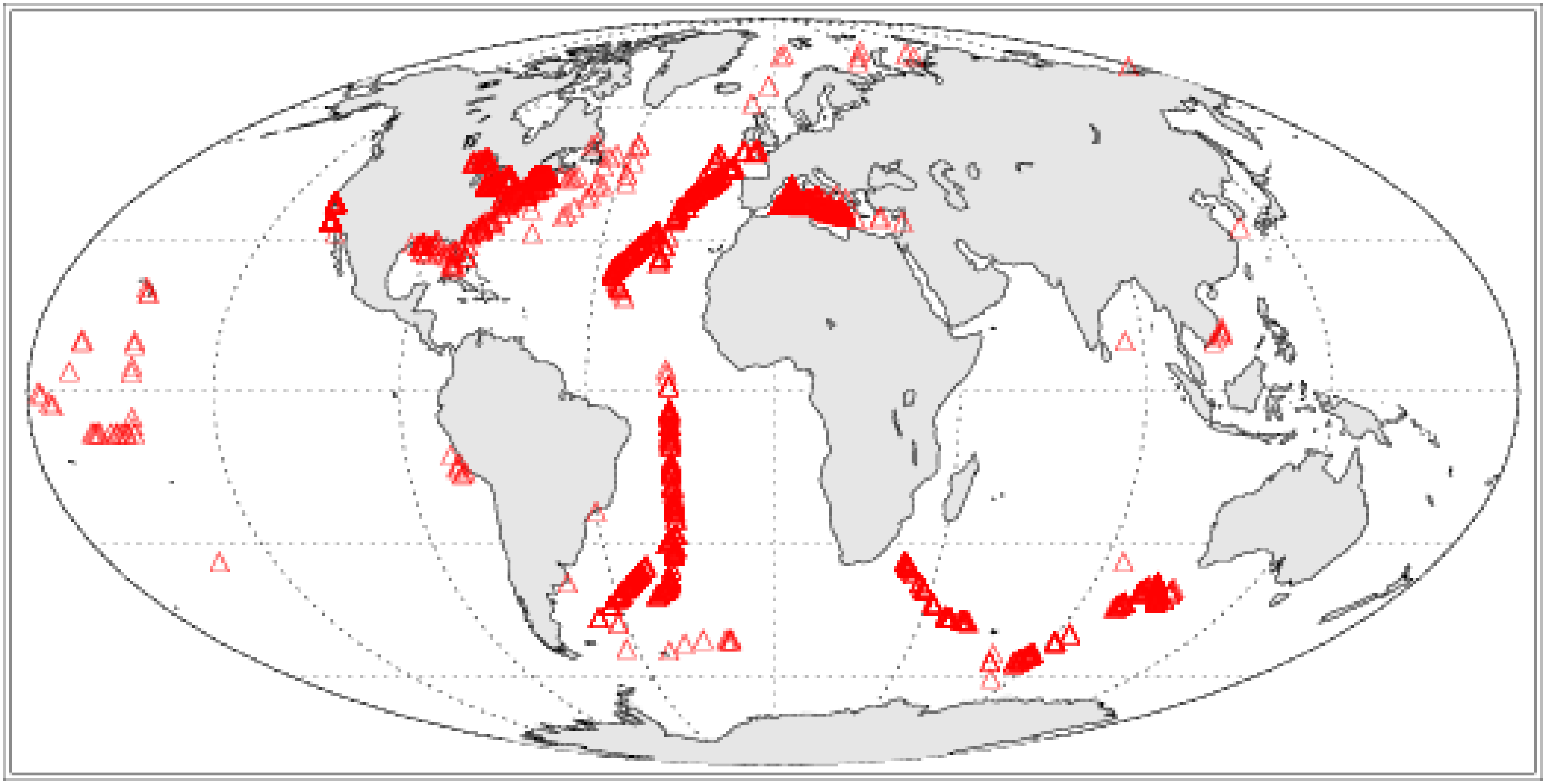
JERD	Requirement	Meet Requirement (Y/N)?
JERD-2128	The algorithm shall produce an OC/C product during clear conditions	Yes
JERD-2129	The algorithm shall produce an OC/C product during daytime conditions	Yes
JERD-2130	The algorithm shall produce an OC/C product that has a horizontal cell size of 0.75 km at nadir (worst case of 1.6 km)	Yes
JERD-2131	The algorithm shall produce an OC/C product that has a mapping uncertainty (3 sigma) of 0.75 at nadir (worst case 1.6 km)	Yes
JERD-2132	The algorithm shall produce an OC/C product that has a measurement range of 0.1 – 50 W/m^2/um/sr for ocean color, 4.6/(10)^2 to 1.0/m for optical properties – absorption, 4.0/(10)^4 to 1.1/(10)^2/m for optical properties – backscattering, and 0.01 to 100 mg/m^3 for chlorophyll	
JERD-2133	The algorithm shall produce an OC/C product that has a measurement precision (**open ocean, blue band**) of: 10% operational (5% science quality) for ocean color, 20% for optical properties, 30% for chlorophyll at Ch1 < 1 mg/m^3 30% for chlorophyll at 1.0 mg/m^3 < Ch1 < 10 mg/m^3, and 50% for chlorophyll at Ch1 > 10 mg/m^3	
JERD-2134	The algorithm shall produce an OC/C product that has a measurement accuracy (**open ocean, blue band**) of: 10% operational (5% science quality) for ocean color 35% operational (25% science quality) for optical properties 35% operational (25% science quality) for chlorophyll at Ch1 < 1 mg/m^3 30% operational (25% science quality) for chlorophyll at 1.0 mg/m^3 < Ch1 < 10 mg/m^3 40% operational (30% science quality) for chlorophyll at Ch1 > 10 mg/m^3	
JERD-2135	The algorithm shall produce an OC/C product that demonstrates that nLw errors in the contributing sensor bands are spectrally correlated as observed in heritage data	

Ocean Color Data Performance Evaluation
(Compared with the In situ data)

- VIIRS-SNPP-derived **Chl-a** data are compared with in situ data from the NASA SeaBASS database. For the global open ocean, VIIRS-SNPP provides excellent Chl-a data, which can be used as references for VIIRS-NOAA-20 Chl-a data quality evaluation.
- Ocean color data from VIIRS on the SNPP and NOAA-20 are routinely compared with in situ measurements from the Marine Optical Buoy (MOBY) in waters off Hawaii (oligotrophic waters).
- MOBY in situ data have high data quality and considered as “truth”.
- Using MOBY in situ data, VIIRS-NOAA-20 ocean color products are evaluated and validated, in particular, for ocean color data derived after April 27, 2018.
- Evaluation results (from comparisons with MOBY in situ data) show that VIIRS-NOAA-20 ocean color data compared well with MOBY in situ measurements and have high data quality.
- Comparison results also show **strong spectral correlation for the errors** in VIIRS-NOAA-20-derived normalized water-leaving radiance spectra.
- VIIRS-NOAA-20-derived $nL_w(\lambda)$ spectra are also compared with those from in situ AERONET-OC measurements (coastal regions).

Locations of SeaBASS in situ Chl-a data in the VIIRS period

Number of measurements matched to VIIRS (Chl-a: 16,255)



Matchup of **Chl-a**

SeaBASS

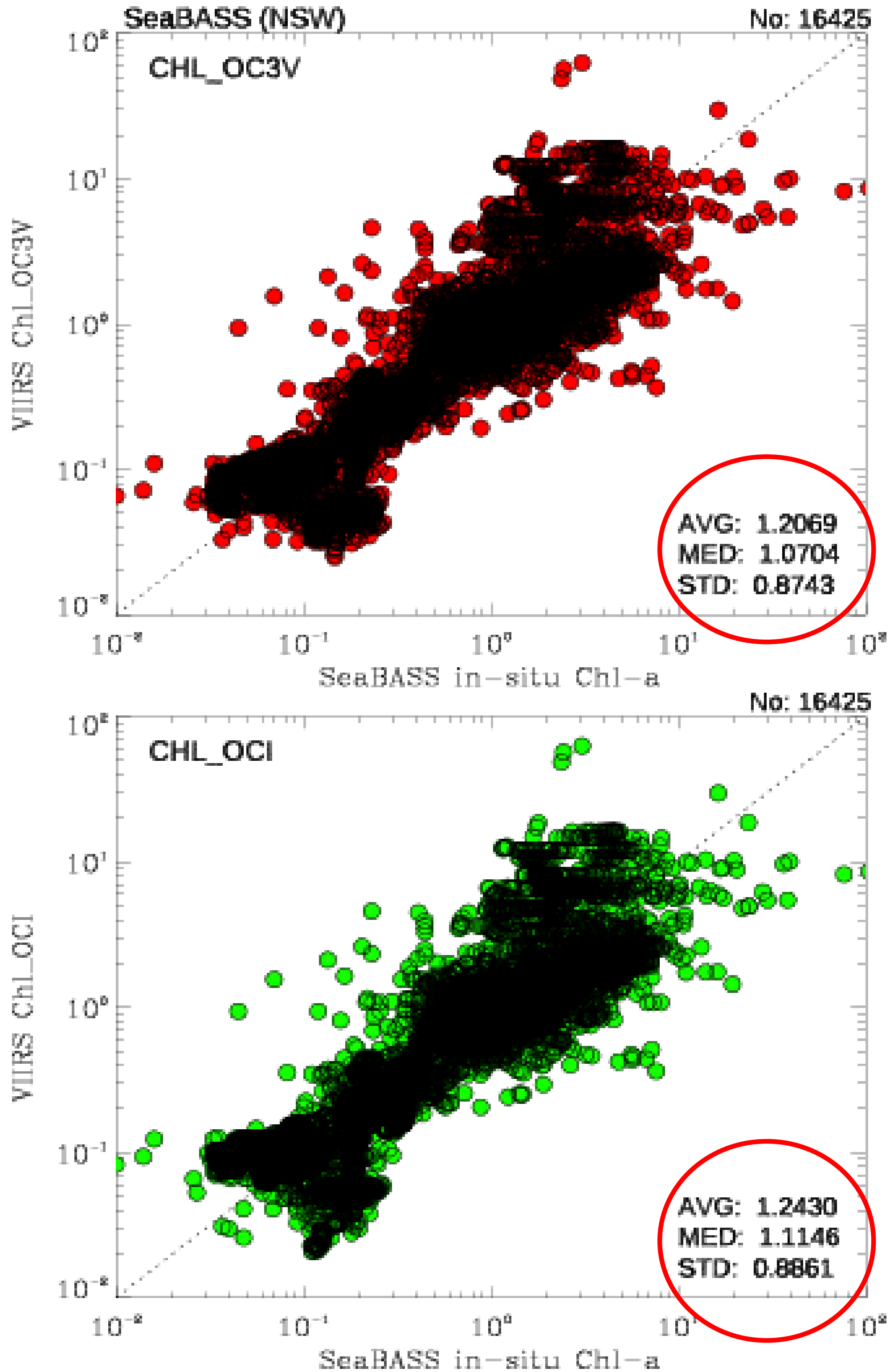
versus

VIIRS-SNPP

(NIR-SWIR)

(Same Day)

Over Global **Open Oceans** and **Coastal/Inland Waters**

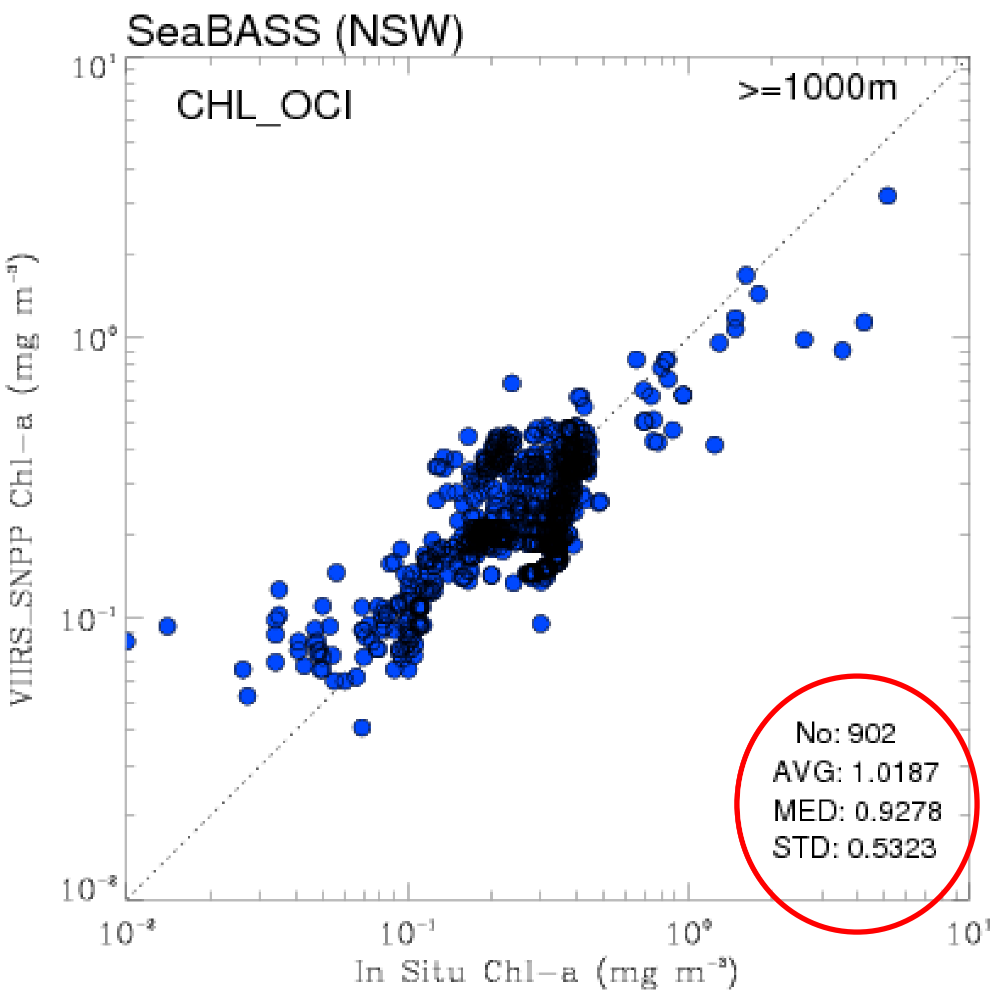


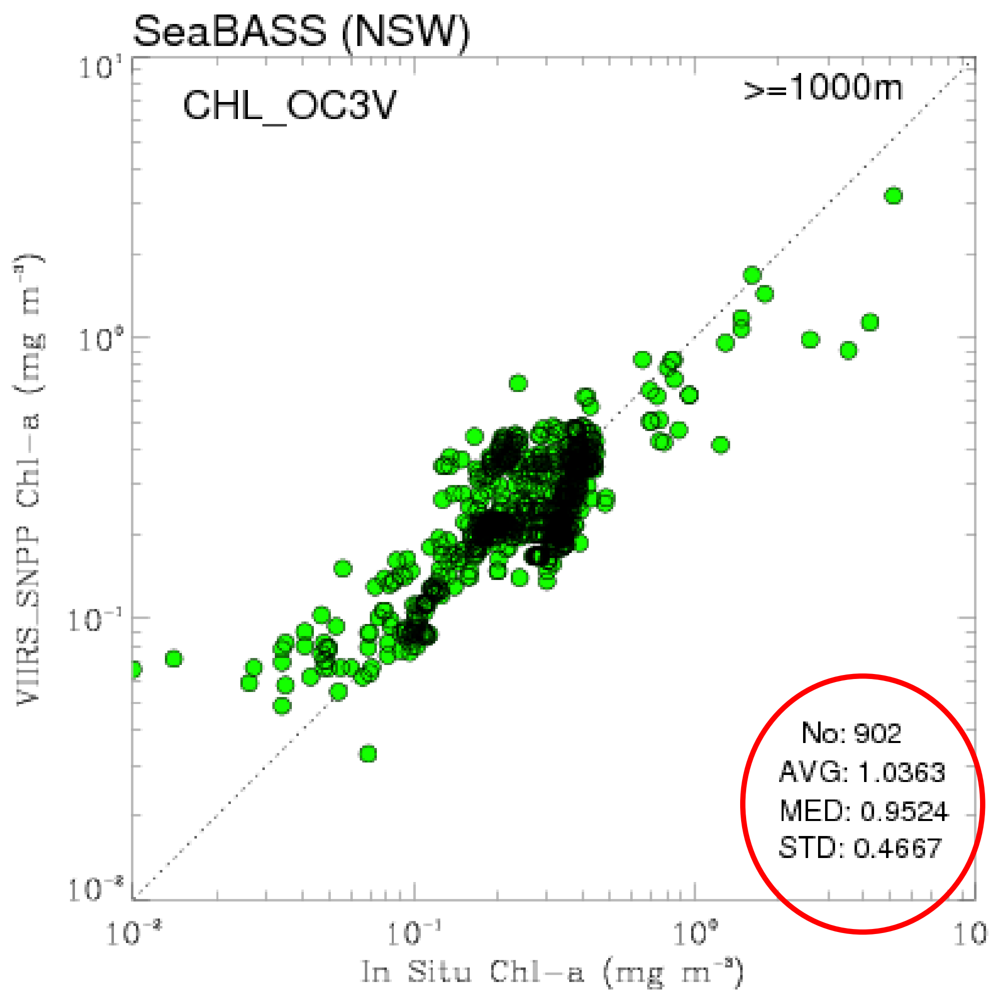
SeaBASS

Matchup of Chl-a

VIIRS-SNPP (NIR-SWIR) VS. SeaBASS In Situ Data

Over Global Deep Water





VIIRS-SNPP Chl-a data have **excellent data quality** over **global open oceans!**

SeaBASS

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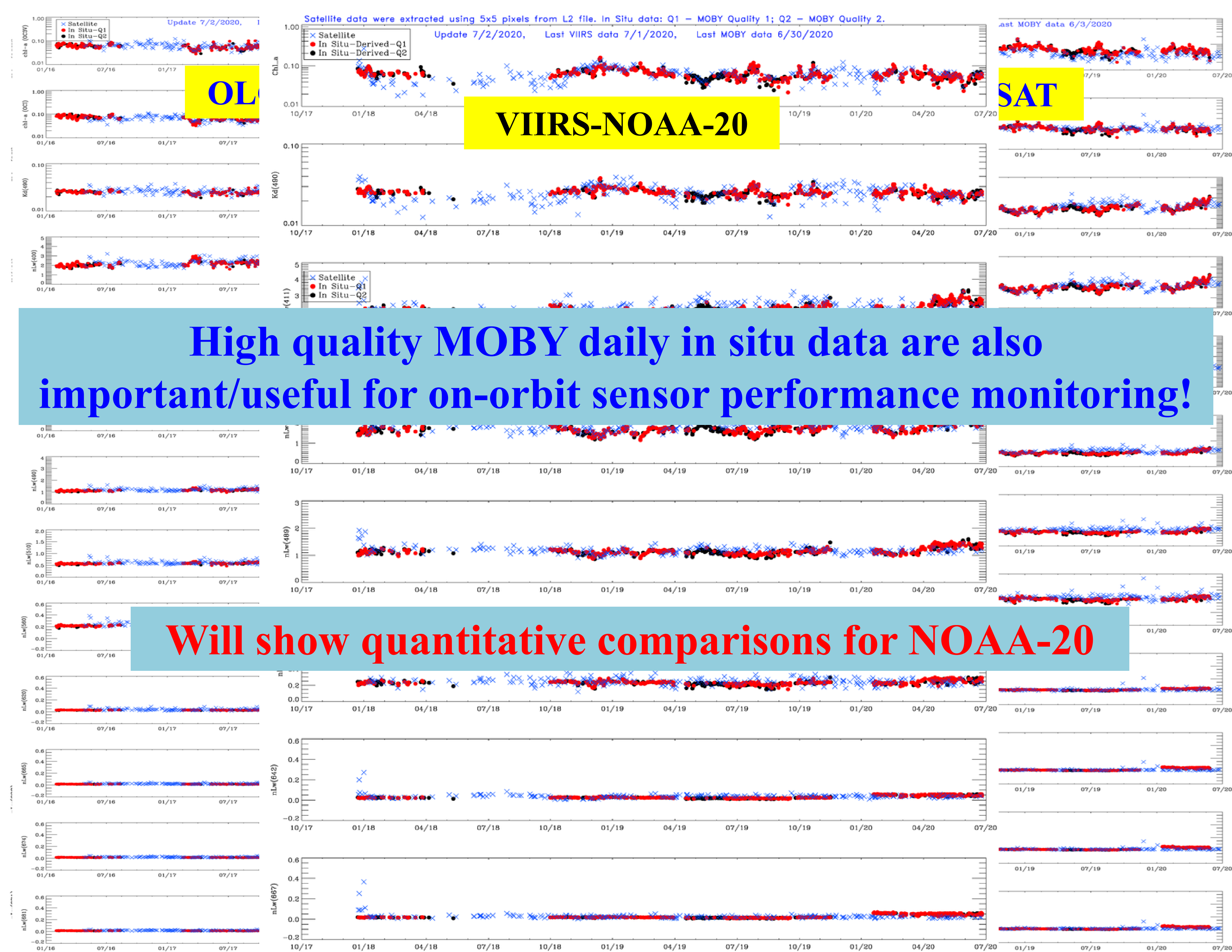


High quality MOBY daily in situ data are also important/useful for on-orbit sensor performance monitoring!

Will show quantitative comparisons for NOAA-20

Matchup of

MOBY In Situ

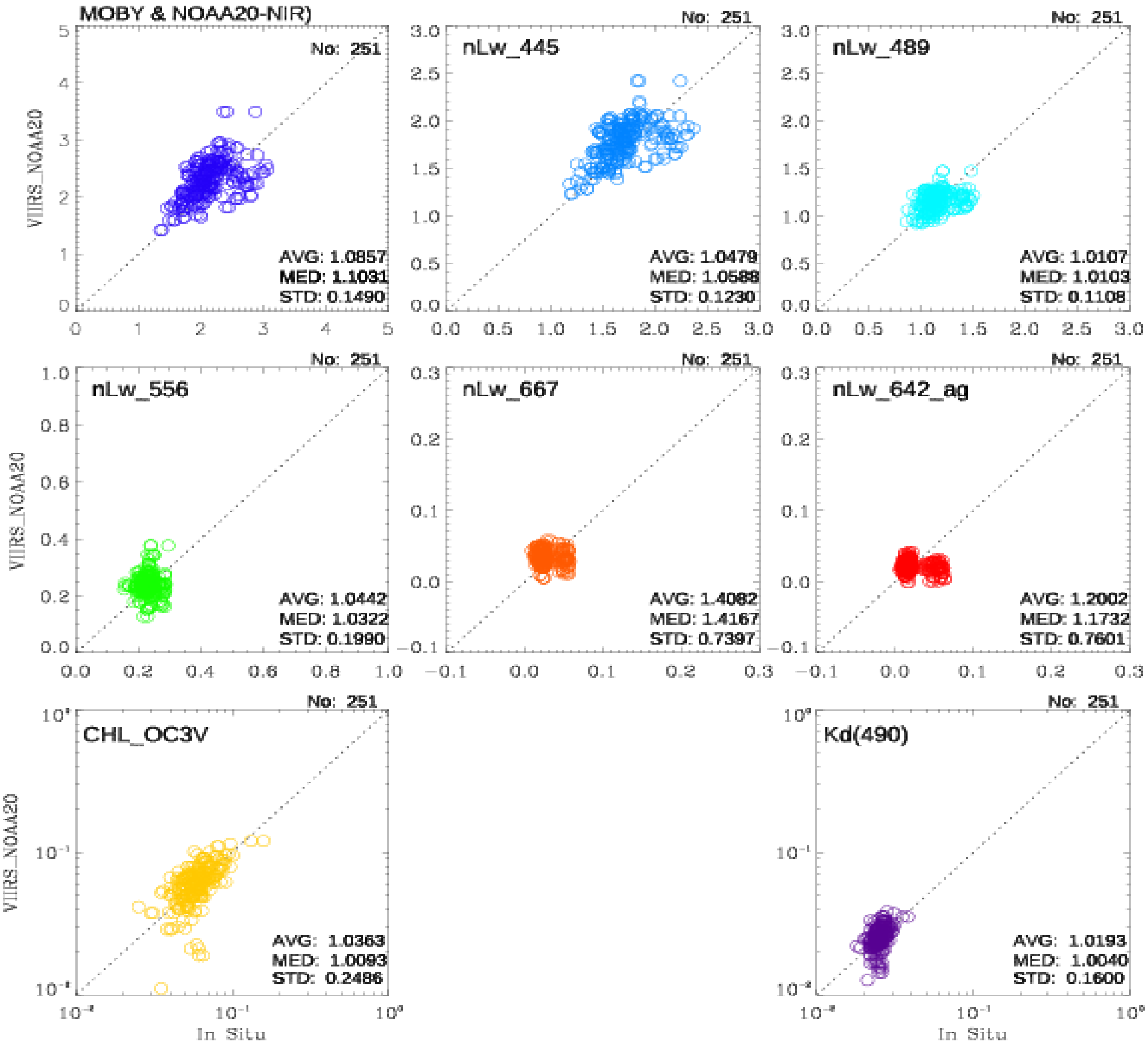
&

VIIRS NOAA-20

(NRT)

(2018-04-27 ~ Now)

Current Routine Global Data Processing



MOBY

(Q1+Q2)

4 L2 Flags

MOBY

Statistics of VIIRS-NOAA-20 vs. In-Situ (MOBY)

*. Current Data Processing (NRT) (2018-04-27 ~ Now)

	VIIRS NOAA-20 (NIR)							
	RATIO (SAT/ENV)				DIFFERENCE (SAT-ENV)			
Parameter	AVG	MED	STD	No	AVG	MED	STD	%Diff
$nL_w(411)$	**1.0857**	1.1031	0.149	251	**0.1579**	0.2065	0.334	7.384
$nL_w(445)$	**1.0479**	1.0588	0.123	251	**0.0658**	0.0948	0.220	3.850
$nL_w(489)$	**1.0107**	1.0103	0.111	251	**0.0030**	0.0124	0.132	0.259
$nL_w(556)$	**1.0442**	1.0322	0.199	251	**0.0073**	0.0076	0.046	3.181
$nL_w(642)$	**1.4082**	1.4167	0.740	251	**0.0049**	0.0097	0.018	16.609
$nL_w(667)$	**1.2002**	1.1732	0.760	251	**-0.0042**	0.0025	0.020	-16.913
Chl-a	**1.0363**	1.0093	0.249	251	**0.0015**	0.0005	0.014	2.554
$K_d(490)$	**1.0193**	1.0040	0.160	251	**0.0005**	0.0001	0.004	1.884

*. MOBY Q1+Q2

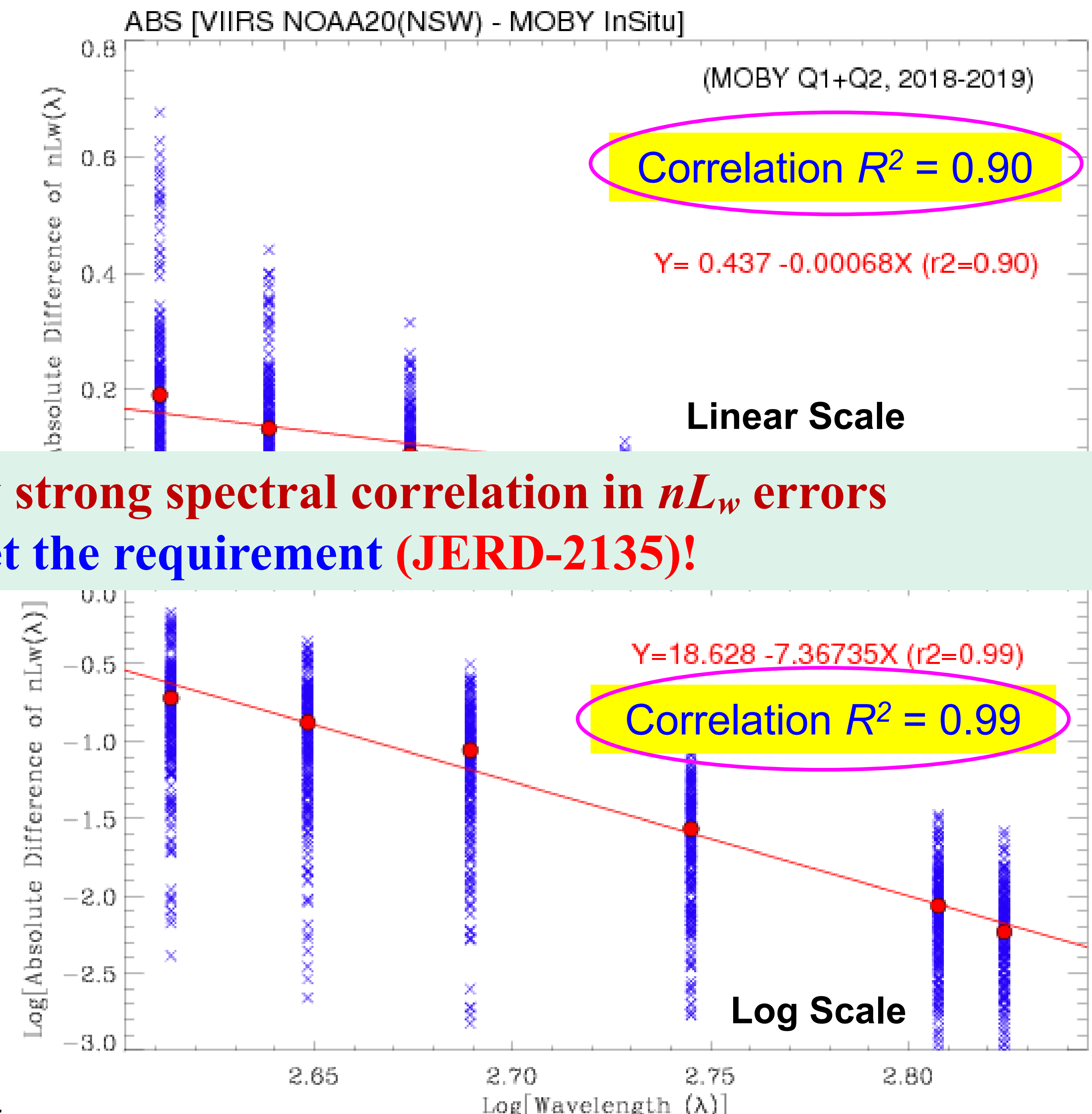
4 L2_Flags (Sensor/Solar Zenith, Glint, Straylight)

Absolute Difference between **VIIRS NOAA-20** & **MOBY In situ data**

(2018–2019)

	AVG	No
$nL_w(410)$	0.1897	215
$nL_w(443)$	0.1316	215
$nL_w(486)$	0.0874	215
$nL_w(551)$	0.0272	215

MOBY Data (Q1+Q2)



Results show strong spectral correlation in nL_w errors

Meet the requirement (JERD-2135)!

*. red-filled circles are **Mean** difference

Matchup of

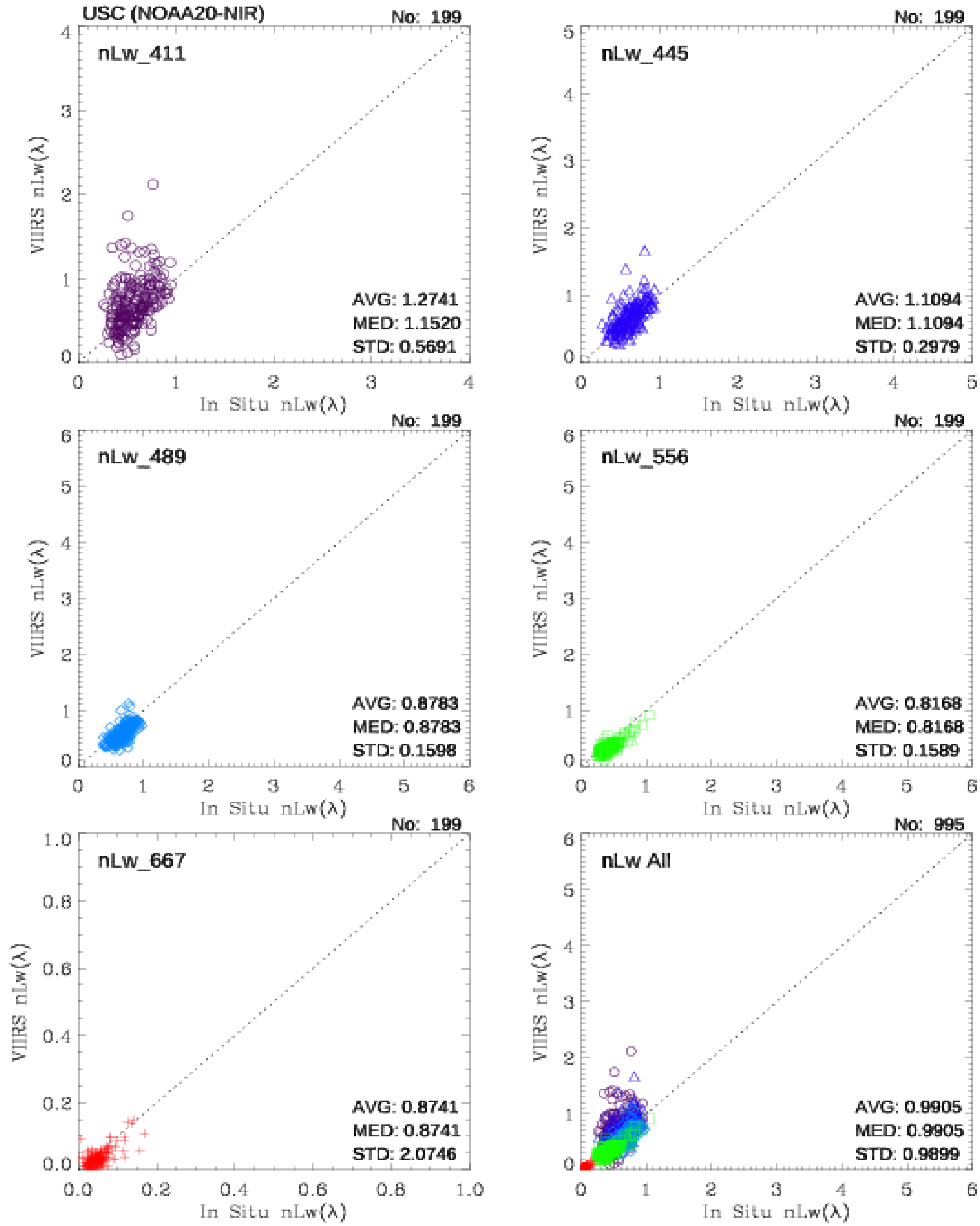
AERONET-OC In Situ

&

VIIRS NOAA-20

USC Site

(**2018-04-27** ~ **Current**)



4 L2 Flags

Statistics of VIIRS-NOAA-20 vs. AERONET-OC

USC Site

***. Current Data Processing (NRT)** **(2018-04-27 ~ Current)**

	VIIRS NOAA-20							
	RATIO (SAT/ENV)				DIFFERENCE (SAT-ENV)			
Parameter	AVG	MED	STD	No	AVG	MED	STD	%Diff
$nL_w(411)$	**1.2741**	1.1520	0.569	199	**0.1321**	0.0864	0.275	23.337
$nL_w(445)$	**1.1094**	1.0752	0.298	199	**0.0566**	0.0479	0.164	9.273
$nL_w(489)$	**0.8783**	0.8666	0.160	199	**-0.0847**	-0.0860	0.109	-12.52
$nL_w(556)$	**0.8168**	0.8016	0.159	199	**-0.0822**	-0.0762	0.071	-19.48
$nL_w(667)$	**0.8741**	0.6455	2.075	199	**-0.0161**	-0.0148	0.021	-32.55
nL_w_ALL	**0.9905**	0.8925	0.990	995	**0.0011**	-0.0250	0.176	0.242

4 L2 Flags (Sensor/Solar Zenith, Glint, Straylight)

Matchup of

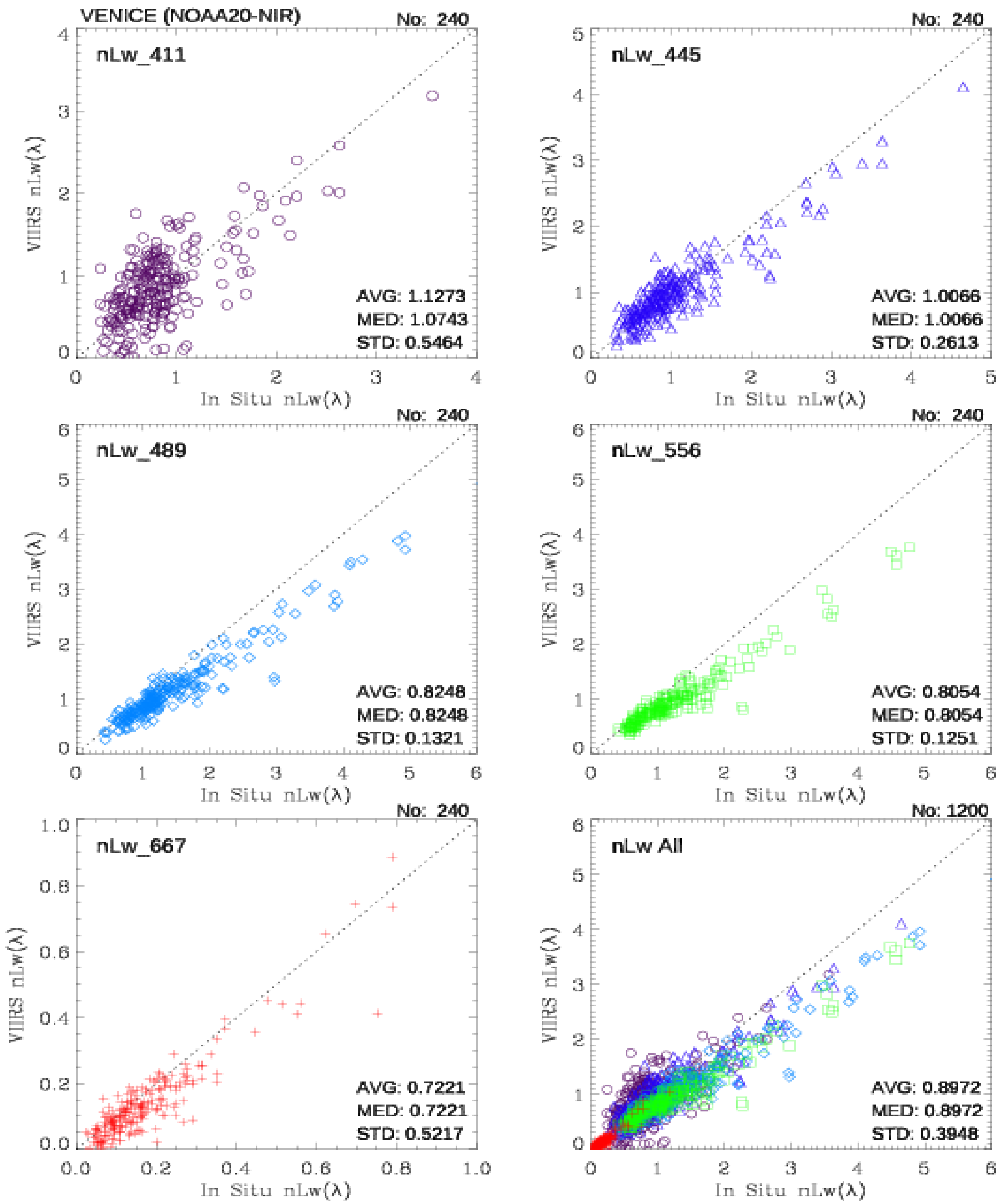
AERONET-OC In Situ

&

VIIRS NOAA-20

VENICE Site

(**2018-04-27** ~ **Current**)



4 L2_Flags

VENICE Site

Statistics of VIIRS-NOAA-20 vs. AERONET-OC

*. Current Data Processing (2018-04-27 ~ Current)

	VIIRS NOAA-20							
	RATIO (SAT/ENV)				DIFFERENCE (SAT-ENV)			
Parameter	AVG	MED	STD	No	AVG	MED	STD	%Diff
$nL_w(411)$	**1.1273**	1.0743	0.546	240	**0.0392**	0.0482	0.355	4.708
$nL_w(445)$	**1.0066**	0.9913	0.261	240	**-0.0452**	-0.0068	0.257	-4.272
$nL_w(489)$	**0.8248**	0.8253	0.132	240	**-0.2833**	-0.2158	0.287	-19.37
$nL_w(556)$	**0.8054**	0.7984	0.125	240	**-0.2792**	-0.1977	0.277	-21.96
$nL_w(667)$	**0.7221**	0.7922	0.522	240	**-0.0367**	-0.0318	0.051	-21.04
nL_w_ALL	**0.8972**	0.8593	0.395	1200	**-0.1211**	-0.0763	0.298	-12.61

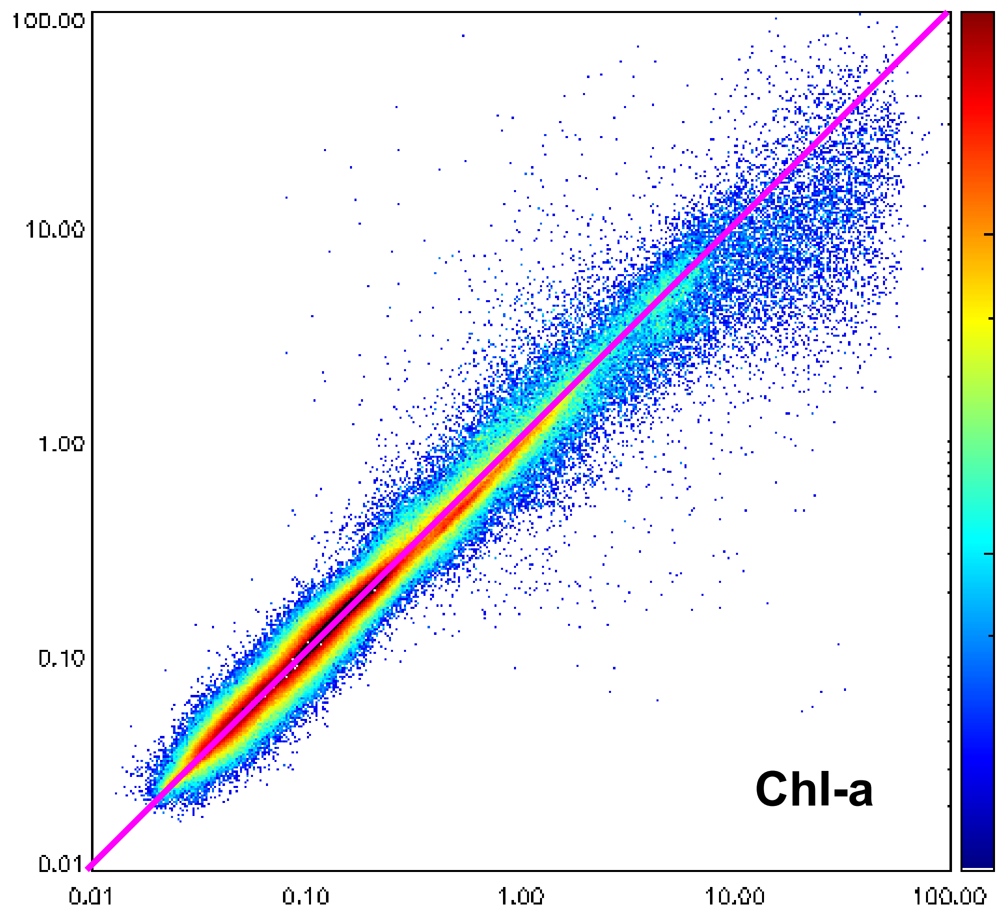
4 L2 Flags (Sensor/Solar Zenith, Glint, Straylight)

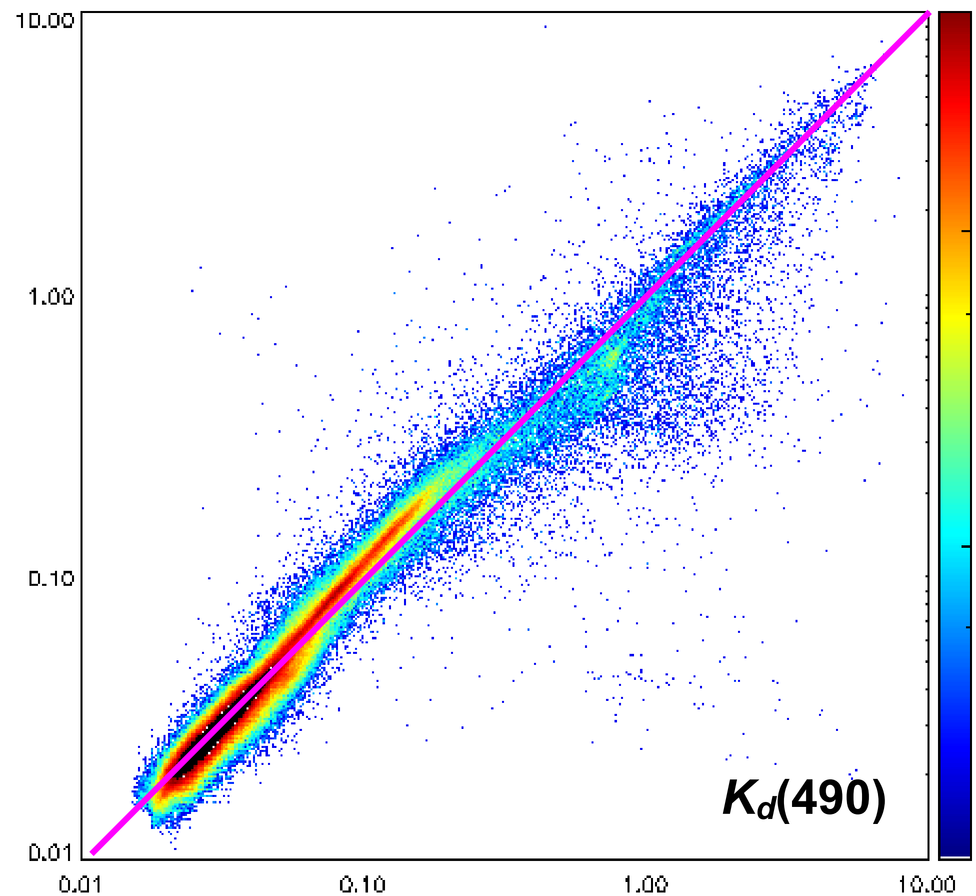
Global Ocean Color Data Performance Evaluation

(NOAA-20 compared with SNPP & OLCI-Sentinel-3A)

- VIIRS-SNPP ocean color data have been well validated, showing high data quality over global oceans. Thus, VIIRS-NOAA-20 ocean color data have been extensively compared and evaluated using VIIRS-SNPP global ocean color data (science quality data).
- VIIRS-NOAA-20 produced global daily, 8-day, and monthly ocean color data have been routinely compared with those from VIIRS-SNPP. They are very comparable, particularly after April 27, 2018. All the results have been routinely shown in the OC website: (https://www.star.nesdis.noaa.gov/socd/mecb/color/).
- In fact, the merged global daily Chl-a data from VIIRS-SNPP and VIIRS-NOAA-20, as well as gap-free global Chl-a data have been routinely produced and distributed through NOAA CoastWatch, showing improved (e.g., coverage) and consistent results, e.g., no observable artifacts. Gap-free Chl-a data have been quantitatively evaluated and shown good results.
- VIIRS-NOAA-20 global ocean color data have been extensively evaluated compared with those from VIIRS-SNPP. Quantitative analysis has been carried out to provide statistics for data accuracy and precision (compared with VIIRS-SNPP).
- Because the evaluation criteria are based on the clear/open ocean waters, evaluation results from VIIRS-NOAA-20-derived ocean color products over global deep waters are specifically presented. Examples from daily comparisons are also presented.
- In addition, VIIRS-NOAA-20 global ocean color data have been extensively compared with those from EUMETSAT OLCI-Sentinel-3A, showing consistent results from the two sensors.
- Our evaluation results show that after April 27, 2018 VIIRS-NOAA-20 ocean color data quality meets the **Validated** data requirements.

OC Performance: Chl-a & K_d(490)
(NOAA-20 Compared with SNPP)



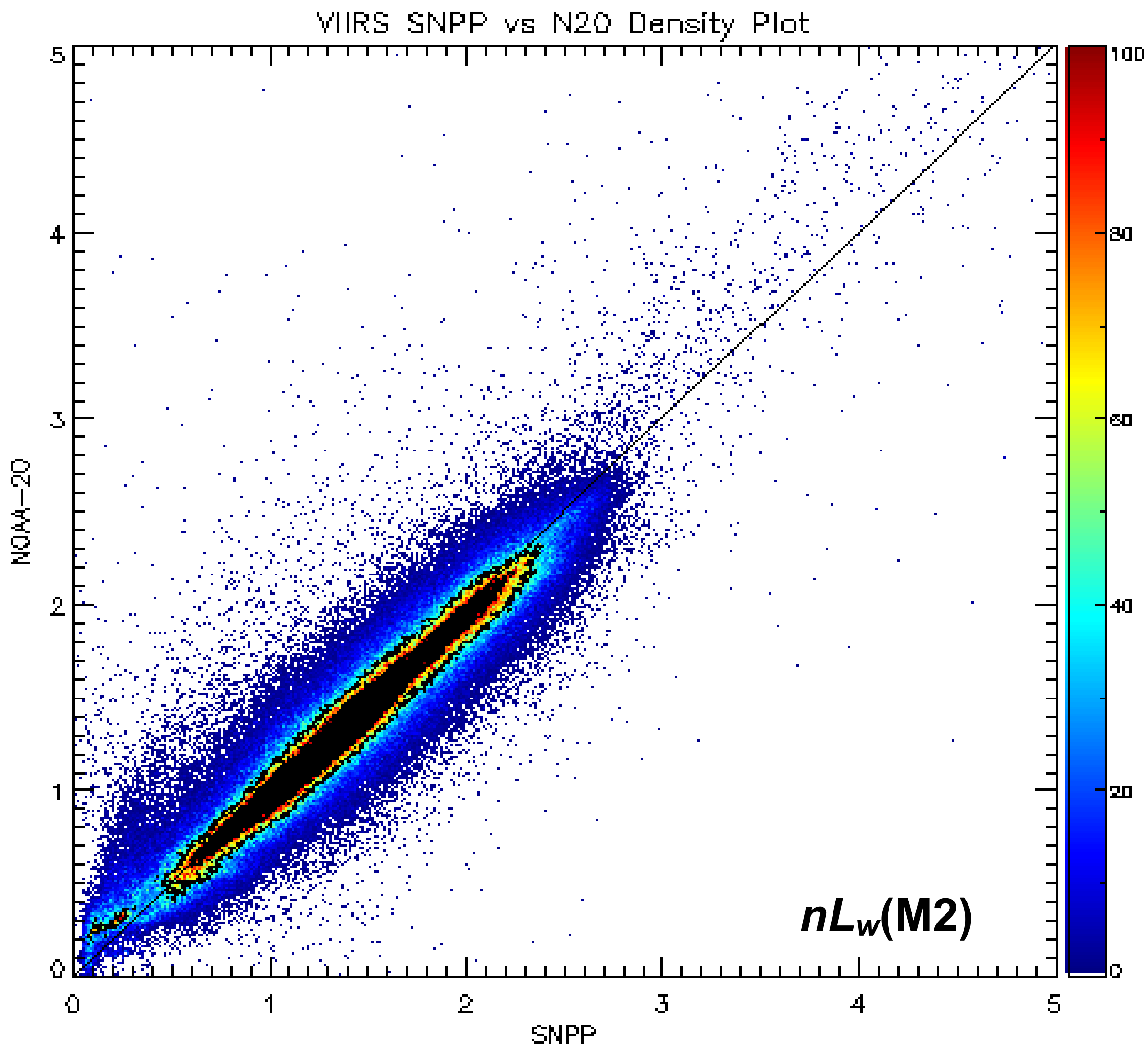


Global Data on June 30, 2018 for All the data

VIIRS-NOAA-20 Chl-a Meets the Requirement of Data Range!
(JERD-2132)

Menghu

OC Performance: nL_w(M2)
(NOAA-20 Compared with SNPP)



Global Data on June 30, 2018 for All the data

VIIRS-NOAA-20 nL_w(M2) Meets the Data Range Requirement! (JERD-2132)

Global $nL_w(445)$ (Blue band) Performance

(NOAA-20 Compared with SNPP)

Menghua Wang, NOAA/NESDIS/STAR

Global Chl-a Performance

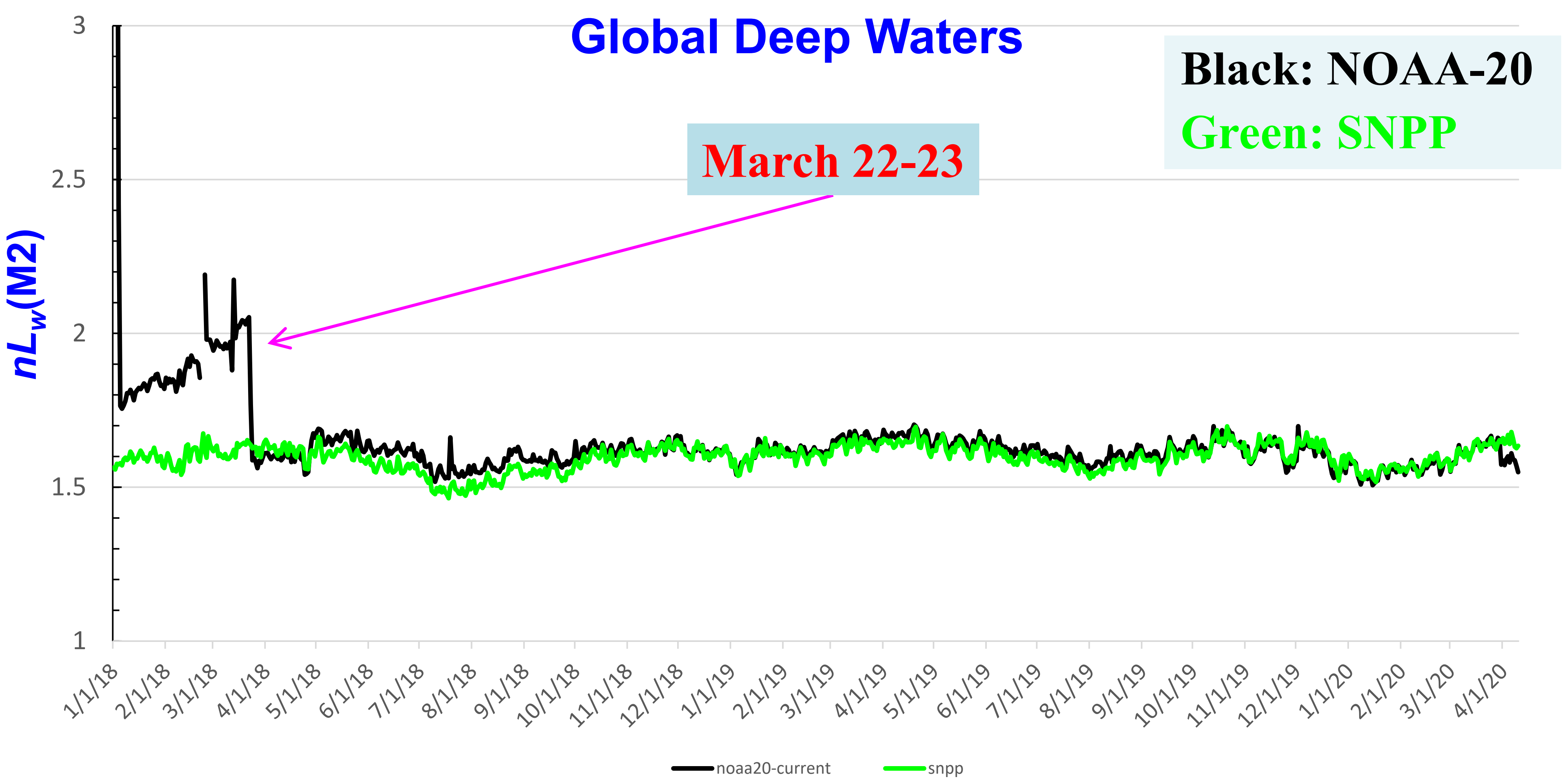
(NOAA-20 Compared with SNPP)

Global Oligotrophic Waters

Menghua Wang, NOAA/NESDIS/STAR

Global $nL_w(445)$ (Blue band) Performance

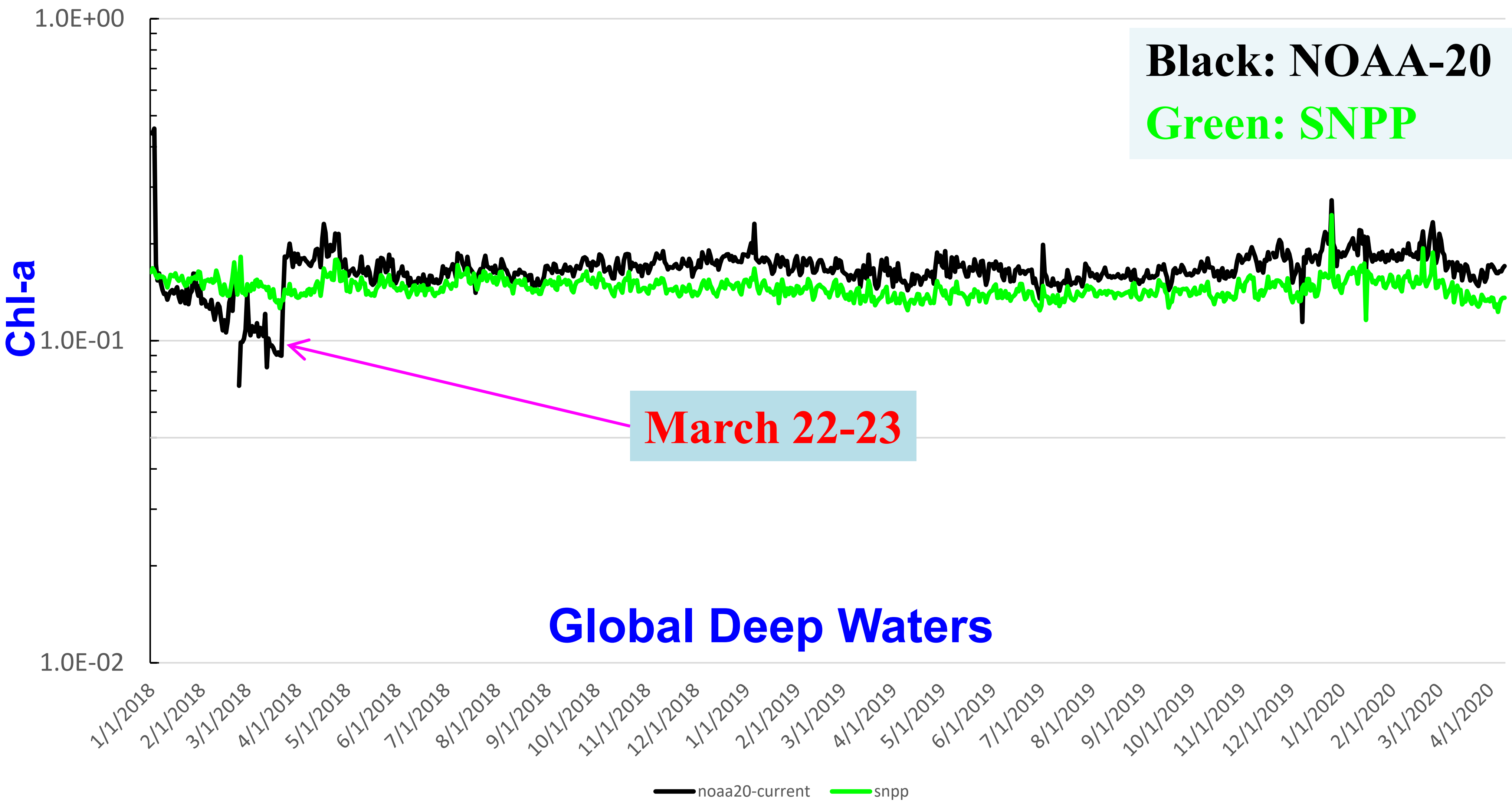
(NOAA-20 Compared with SNPP)



Menghua Wang, NOAA/NESDIS/STAR

Global Chl-a Performance

(NOAA-20 Compared with SNPP)



Menghua Wang, NOAA/NESDIS/STAR

Blue nL_w(M2) Statistics: Accuracy and Precision

(NOAA-20 Compared with SNPP)

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

Dates	Global Oligotrophic Waters		Global Deep Waters		Global Coastal/Inland Waters	
Parameter (Requirement)	**Mean** (5/10%)	**Median** (5/10%)	**Mean** (5/10%)	**Median** (5/10%)	**Mean** (N/A)	**Median** (N/A)
After April 27	**1.0091**	**1.0081**	**1.0111**	**1.0104**	1.0225	1.0242

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

Dates	Global Oligotrophic Waters	Global Deep Waters	Global Coastal/Inland Waters
Parameter (Requirement)	**STD** (5/10%)	**STD** (5/10%)	**STD** (N/A)
After April 27	**0.0155**	**0.0168**	0.0366

VIIRS-NOAA-20 Blue nL_w(M2) Meets the Requirements!

(JERD-2133 and 2134)

Menghu… g,

Chl-a Statistics: Accuracy and Precision

(NOAA-20 Compared with SNPP)

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

Dates	Global Oligotrophic Waters		Global Deep Waters		Global Coastal/Inland Waters	
Parameter (Requirement)	Mean (25/35%)	Median (25/35%)	Mean (25/30%)	Median (25/30%)	Mean (N/A)	Median (N/A)
After April 27	**1.0520**	**1.0487**	**1.1673**	**1.1676**	1.5037	1.5153

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

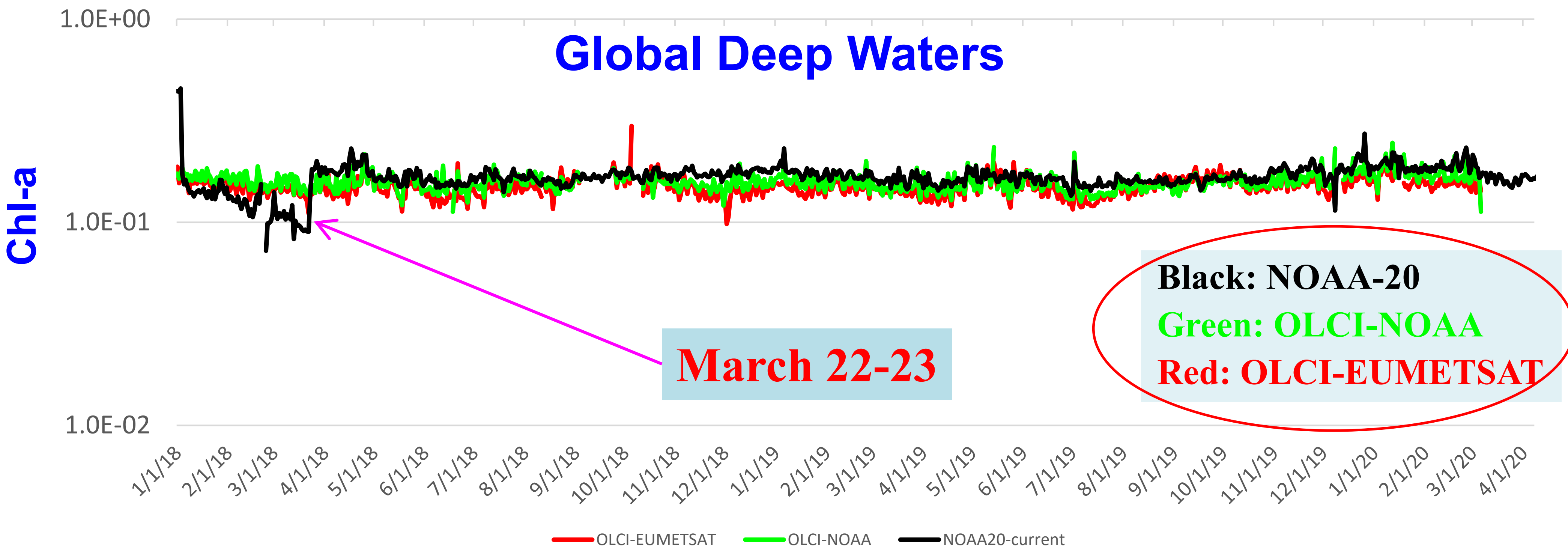
Dates	Global Oligotrophic Waters	Global Deep Waters	Global Coastal/Inland Waters
Parameter (Requirement)	STD (30%)	STD (30%)	STD (N/A)
After April 27	**0.0628**	**0.0686**	0.1675

VIIRS-NOAA-20 Chl-a Meets the Requirements!
(JERD-2133 and 2134)

Menghu... g,

Global Chl-a Performance

(VIIRS-NOAA-20 Compared with OLCI-Sentinel-3A)



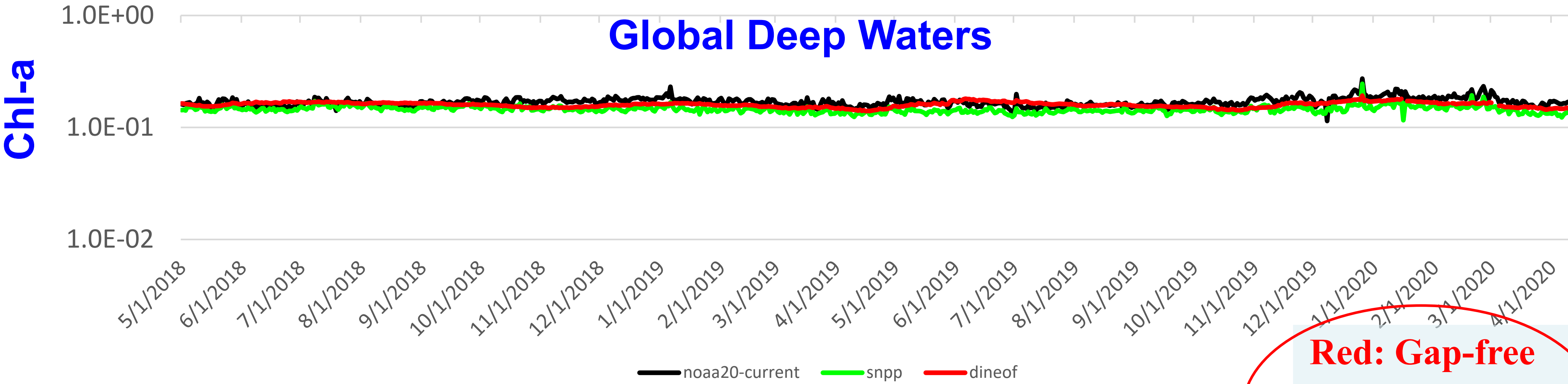
Accuracy/Precision: Mean, Median, and STD of **Chl-a VIIRS/OLCI** Ratio

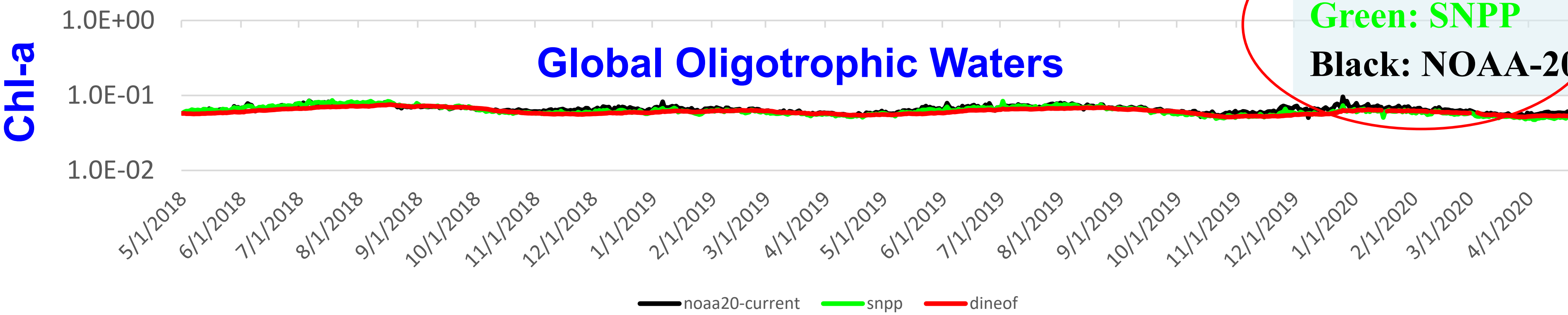
Dates	OLCI-EUMETSAT			OLCI-NOAA		
Parameter (Requirement)	**Mean** (25/35%)	**Median** (25/35%)	**STD** (30%)	**Mean** (25/30%)	**Median** (25/30%)	**STD** (30%)
After April 27	**1.1387**	**1.1439**	**0.1160**	**1.0763**	**1.0772**	**0.0930**

VIIRS-NOAA-20 Chl-a Meets the Requirements!
(JERD-2133 and 2134)

Global Gap-free Chl-a Performance

(Gap-free Chl-a Compared with SNPP and NOAA-20)





Red: Gap-free
Green: SNPP
Black: NOAA-20

Accuracy/Precision (Global Deep Waters):

Ratios in Mean, Median, and STD of Gap-free **Chl-a** vs. SNPP and NOAA-20

Dates	Gap-free vs. SNPP			Gap-free vs. NOAA-20		
Parameter (Requirement)	**Mean** (25/35%)	**Median** (25/35%)	**STD** (30%)	**Mean** (25/30%)	**Median** (25/30%)	**STD** (30%)
After April 27	**1.1027**	**1.0951**	**0.0691**	**0.9483**	**0.9361**	**0.0812**

MSL12 Major Updates (v1.40)

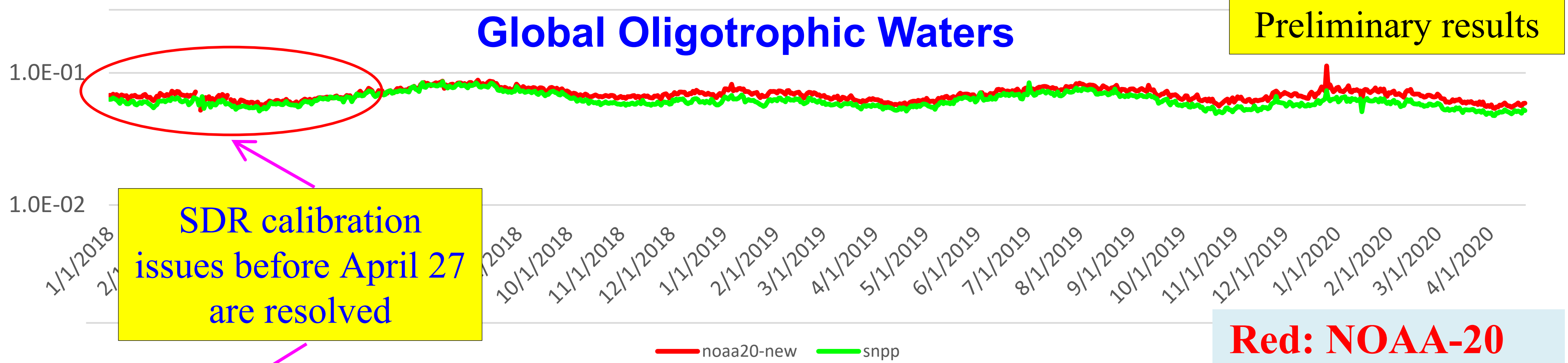
(Going Forward Plan/Work)

- Added multiple NetCDF4 Level-2 files output capability.
- New improved land mask with 250 m spatial resolution globally.
- Revised to use band ratio information at open ocean only to derive products from multiple sensors for consistent ocean color results (*Wang et al.*, 2020).
- New improved NIR-QAA algorithm to derive IOPs over global open oceans and turbid coastal/inland waters (*Shi & Wang*, 2019).
- Updated the blue-band corrections using both the short blue band information (*Wang & Jiang*, 2018) and the radiance spectral information (*Wei et al.*, 2020), which can now also deal with negative Rayleigh-corrected reflectance cases.
- Updated radiance spectra database (LUTs) for the QA score calculation.
- Modified f/Q effect correction to only apply to open oceans.
- Updated sensor files to use the sensor SRF-weighted water IOP coefficients.
- Improved cloud shadow and straylight flags (*Jiang and Wang*, 2013) for VIIRS-NOAA-20 using the band relationship between NOAA-20 and SNPP for $nL_w(551)$ climatology at open oceans.
- Added two new flags: NEGLRC (negative Rayleigh-corrected radiance) and LOWLWCORR (low $nL_w(\lambda)$ values at the blue band/corrections applied).
- Fixed a VIIRS sensor sub-region bug (straylight flag) due to different aggregation zones.
- Fixed several minor bugs.

Global Chl-a Performance (MSL12 v1.40)

(NOAA-20 Compared with SNPP)

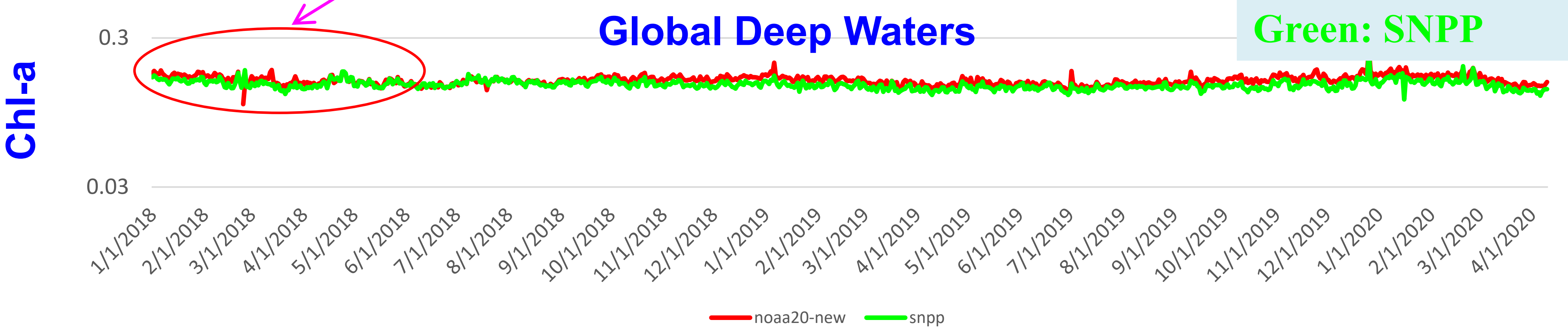
Preliminary results

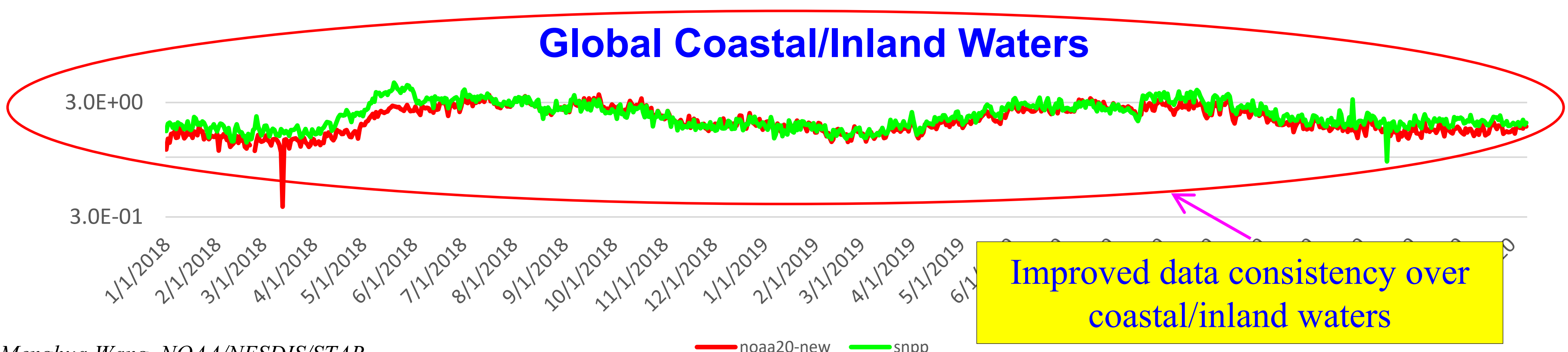


SDR calibration issues before April 27 are resolved

Red: NOAA-20

Green: SNPP





Improved data consistency over coastal/inland waters

Menghua Wang, NOAA/NESDIS/STAR

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

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

Dates	Global Oligotrophic Waters		Global Deep Waters		Global Coastal/Inland Waters	
Parameter (Requirement)	Mean (25/35%)	Median (25/35%)	Mean (25/30%)	Median (25/30%)	Mean (N/A)	Median (N/A)
Mission-long	1.1081	1.1095	1.0718	1.0757	0.9140	0.9167

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

Dates	Global Oligotrophic Waters	Global Deep Waters	Global Coastal/Inland Waters
Parameter (Requirement)	STD (30%)	STD (30%)	STD (N/A)
Mission-long	0.0576	0.0508	0.1128

Much improved VIIRS-NOAA-20 Chl-a Data!

Menghua Wang, NOAA/NESDIS/STAR

Preliminary results

MSL12 v1.40

K_d(490) Statistics: Accuracy and Precision (NOAA-20 Compared with SNPP)

Accuracy: Mean and Median of ***K_d*(490)** NOAA-20/SNPP Ratio

Dates	Global Oligotrophic Waters		Global Deep Waters		Global Coastal/Inland Waters	
Parameter	**Mean**	**Median**	**Mean**	**Median**	**Mean**	**Median**
Mission-long	**0.9743**	**0.9802**	**0.9661**	**0.9703**	**0.8860**	**0.8858**

Precision: Standard Deviation (STD) of ***K_d*(490)** NOAA-20/SNPP Ratio

Dates	Global Oligotrophic Waters	Global Deep Waters	Global Coastal/Inland Waters
Parameter	**STD**	**STD**	**STD**
Mission-long	**0.0462**	**0.0495**	**0.0695**

Preliminary results

MSL12 v1.40

Menghua Wang, NOAA/NESDIS/STAR

User Feedback

Some known users of NOAA-20 OC from CoastWatch Central Servers

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 N-20 OC files of interest.

User Feedback

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

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.

User Feedback

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

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.*

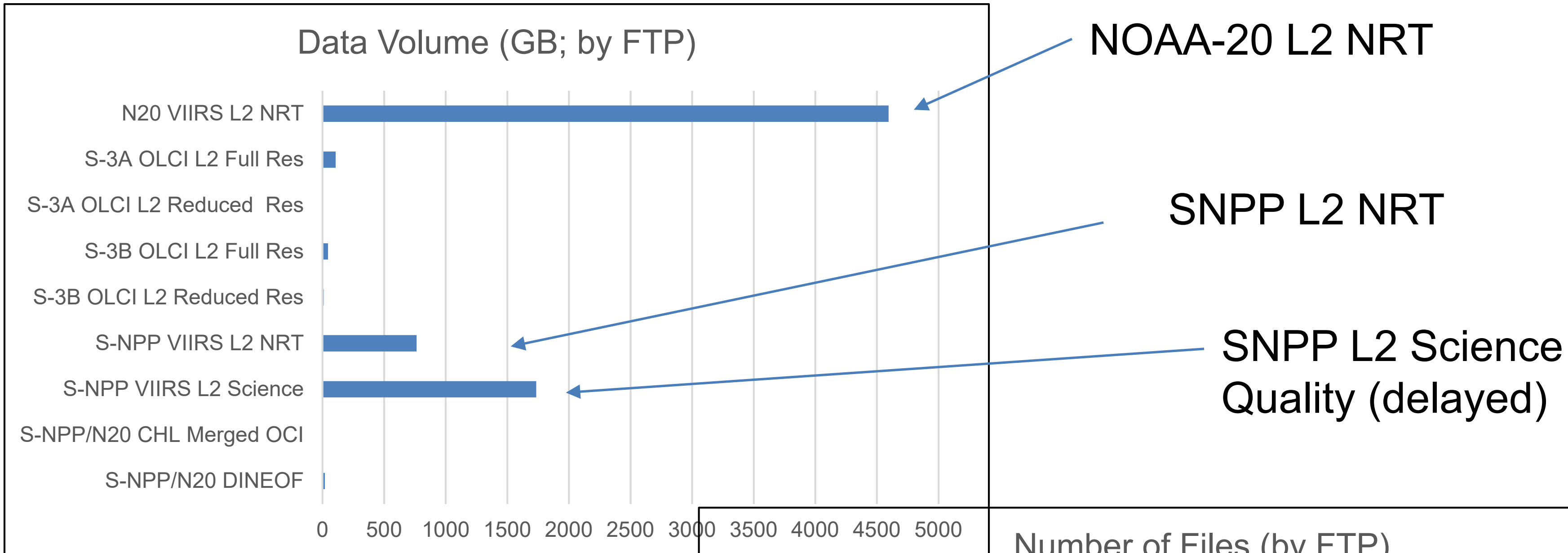
User Feedback

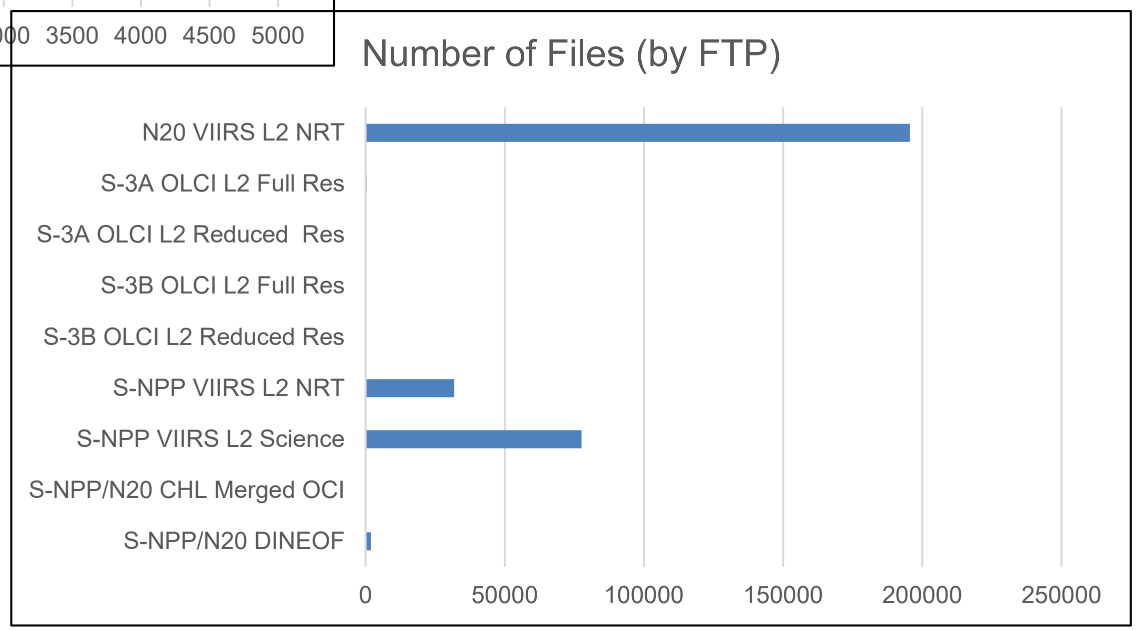
VIIRS-NOAA-20 Access through OSPO Services

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
CLASS	Archive the NOAA-20 OC products
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

User Feedback

L2 OC usage from CoastWatch Central FTP Server (Last 6-month)

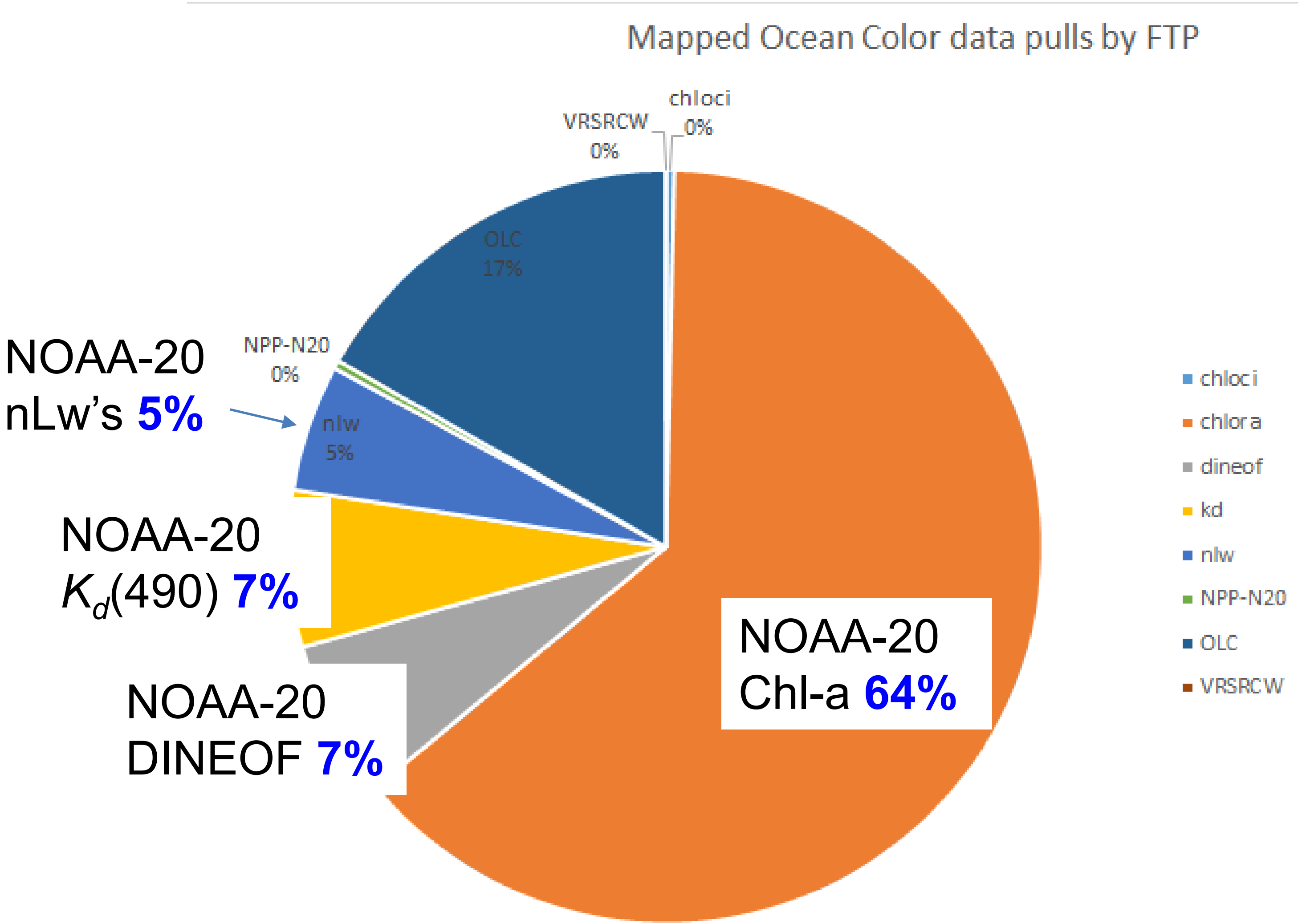




These are only part of OC data user results. There are many users use VIIRS OC data through other means, e.g., OCView imageries, etc.

User Feedback

VIIRS OC MAPPED (e.g., L3) product usage from CoastWatch Central FTP Server



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

Check List - Validated Maturity

Validated Maturity End State	Assessment
Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).	**Yes**—OC products have been extensively evaluated using MOBY in situ data, AERONET-OC in situ data, VIIRS-SNPP and OLCI global ocean color data, showing good quality data after April 27, 2018.
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.	**Yes**—Quantitative statistics results from in situ and global satellite data are provided.
Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.	**Yes**—As demonstrated in the presentation (extensive data quality analyses).
Product is ready for operational use based on documented validation findings and user feedback.	**Yes**—OC products are in operations since 2018 and no issues revealed from user feedback.
Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument	**Yes**—For VIIRS data derived after April 27, 2018. OC data will be reprocessed for the entire mission.

Requirement Check List – Ocean Color/Chlorophyll

JERD	Requirement	Meet Requirement (Y/N)?
JERD-2128	The algorithm shall produce an OC/C product during clear conditions	**Yes**
JERD-2129	The algorithm shall produce an OC/C product during daytime conditions	**Yes**
JERD-2130	The algorithm shall produce an OC/C product that has a horizontal cell size of 0.75 km at nadir (worst case of 1.6 km)	**Yes**
JERD-2131	The algorithm shall produce an OC/C product that has a mapping uncertainty (3 sigma) of 0.75 at nadir (worst case 1.6 km)	**Yes**
JERD-2132	The algorithm shall produce an OC/C product that has a measurement range of 0.1 – 50 $W/m^2/um/sr$ for ocean color, $4.6/(10)^2$ to 1.0/m for optical properties – absorption, $4.0/(10)^4$ to $1.1/(10)^2/m$ for optical properties – backscattering, and 0.01 to 100 mg/m^3 for chlorophyll	**Yes** (N/A for IOP data)
JERD-2133	The algorithm shall produce an OC/C product that has a measurement precision (**open ocean, blue band**) of: 10% operational (5% science quality) for ocean color, 20% for optical properties, 30% for chlorophyll at Ch1 < 1 mg/m^3 30% for chlorophyll at 1.0 mg/m^3 < Ch1 < 10 mg/m^3, and 50% for chlorophyll at Ch1 > 10 mg/m^3	**Yes** (Note: no large Chl-a over open oceans, N/A for IOP data)
JERD-2134	The algorithm shall produce an OC/C product that has a measurement accuracy (**open ocean, blue band**) of: 10% operational (5% science quality) for ocean color 35% operational (25% science quality) for optical properties 35% operational (25% science quality) for chlorophyll at Ch1 < 1 mg/m^3 30% operational (25% science quality) for chlorophyll at 1.0 mg/m^3 < Ch1 < 10 mg/m^3 40% operational (30% science quality) for chlorophyll at Ch1 > 10 mg/m^3	**Yes** (Note: no large Chl-a over open oceans, N/A for IOP data)
JERD-2135	The algorithm shall produce an OC/C product that demonstrates that nLw errors in the contributing sensor bands are spectrally correlated as observed in heritage data	**Yes**

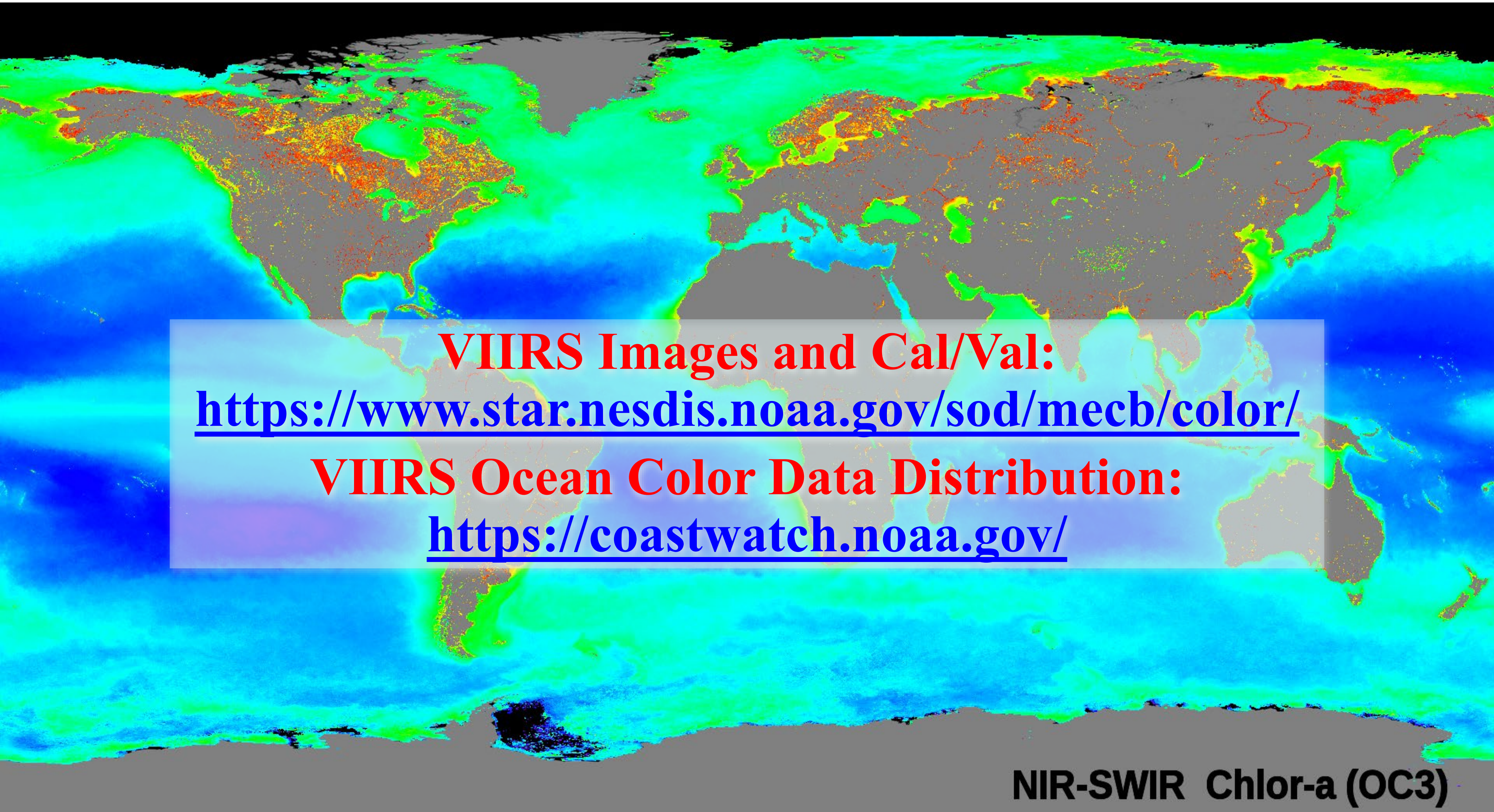
Requirement Check List – Ocean Color/Chlorophyll

JERD	Requirement	Performance
DPS-88	The Ocean Color/Chlorophyll product shall provide ocean color (nLw), chlorophyll-a, and optical properties; 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 with a measurement precision of 10%, over the measurement range of the instrument	**Yes** (Blue Band & Open Oceans)
DPS-89	The Ocean Color/Chlorophyll product shall provide optical properties with a measurement precision of 20%, over the measurement range of the instrument	**Yes** (Blue Band & Open Oceans)
DPS-91	The Ocean Color/Chlorophyll product shall provide chlorophyll-a density with a measurement precision of 30% below 10 mg/m^3, and 50% at and above 10 mg/m^3, over the measurement range of the instrument	**Yes** (Blue Band & Clear Waters)
DPS-93	The Ocean Color/Chlorophyll product shall provide ocean color with a measurement accuracy of 10%	**Yes** (Blue band & Open Oceans)
DPS-94	The Ocean Color/Chlorophyll product shall provide optical properties with a measurement accuracy of 35%	**Yes** (Open Oceans)
DPS-95	The Ocean Color/Chlorophyll product shall provide chlorophyll-a density with a measurement accuracy of 35% below 10 mg/m^3, and 40% at and above 10 mg/m^3	**Yes** (Open Oceans)

Going Forward: Future Plans

- The VIIRS mission-long OC EDR data reprocessing will be carried out for both SNPP and NOAA-20 to include some significant algorithm improvements, i.e., using the improved **MSL12 v1.40** (note: the last VIIRS-SNPP mission-long data reprocessing was carried out in March 2017).
  - For VIIRS-NOAA-20, the SDR calibration issues before April 27, 2018 have been corrected and will be used for VIIRS-NOAA-20 mission-long OC data reprocessing, providing consistent VIIRS-NOAA-20 mission-long global OC product data.
  - With both VIIRS SNPP and NOAA-20 mission-long data reprocessing, global OC data from the two VIIRS sensors are consistent. Therefore, global Chl-a data from the two sensors merged and gap-free data will be routinely generated.
  - Mission-long reprocessed VIIRS data for both SNPP and NOAA-20 will be released to the public when they are done.
  - Global routine NRT OC data processing for both SNPP and NOAA-20 will be using MSL12 v1.40.
- The JPSS Ocean Color Cal/Val team will finish the 2019 VIIRS dedicated cruise report and in situ data analyses (e.g., improve in situ data quality). In addition, the ocean color Cal/Val team will look for the possibility to carry out the 2021 VIIRS dedicated cruise in the spring 2021. These dedicated cruise in situ data will be used for VIIRS-NOAA-20 (and other VIIRS) ocean color data validation.
- More in situ data are needed and will be provided from the OC Cal/Val team.
- We will continue working on (improving) in situ data quality, e.g., 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 coastal/inland waters. In particular, significant efforts are needed for coastal/inland waters.
- Continue working on VIIRS ocean color data applications for users.
- The OC team has been preparing for/will continue working on the JPSS-2 launch in 2022.

Thank You!



VIIRS Images and Cal/Val:
https://www.star.nesdis.noaa.gov/sod/mecb/color/

VIIRS Ocean Color Data Distribution:
https://coastwatch.noaa.gov/

STAR Ocean Color

Chlorophyll-a (OC3) (mg m^{-3})

0.01 0.1 1 10 64

NOAA-20 VIIRS climatology
January 2018 - May 2020

Menghua Wang, NOAA/NESDIS/STAR