Provisional Maturity Science Review For NOAA-20 Ocean Color Algorithm

Presented by Menghua Wang

Date: 2018/11/27

JPSS
NOAA NASA

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— PROVISIONAL MATURITY REVIEW MATERIAL

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, X. Liu, W. Shi, S. Son, L. Tan, X. Wang, J. Sun, K. Mikelsons, M. Chu, V. Lance, **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
Ocean Color	**Robert Arnone** Sherwin Ladner, Adam Lawson, Jen Bowers	U. Southern MS, NRL, QinetiQ Corp., SDSU	JPSS/NJO	Satellite matchup tool (SAVANT) – Golden Regions, Cruise participation and support WAVE_CIS (AERONET-OC site) operation
	Carol Johnson	NIST	JPSS/NJO	Traceability, AERONET Uncertainty
	Nicholas Tufillaro, Curt Davis	OSU	JPSS/NJO	Ocean color validation, Cruise data matchup West Coast
	Burt Jones, Matthew Ragan	USC	JPSS/NJO	Eureka (AERONET Site)
	Alex Gilerson, **Sam Ahmed**	CUNY	JPSS/NJO	LISCO (AERONET 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, Jianwei Wei	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

- 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.
- NOAA-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, & others.
  - ✓ In 2014, some new algorithms (BMW–new NIR reflectance correction, Destriping, K_d(PAR), etc.)
- NOAA-MSL12 for VIIRS (and others) 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, GOCI, and will also add J1, OLCI/Stentinel-3, and SGLI/GCOM-C data processing capability.

MSL12 Level-2 Flags/Masks

No.	Name	Description
1	ATMFAIL	Atmospheric correction failure
2	LAND	Pixel is over land (mask)
3	BADANC	Bad ancillary input files
4	HIGLINT	High sun glint (set if glint reflectance exceeds 0.01)
5	HILT	Observed radiance very high or saturated
6	HISATZEN	High sensor view zenith angle (set if exceeds 60 degree)
7	COASTZ	Land adjacent effect is likely
8	NEGLW	Negative water-leaving radiance
9	STRAYLIGHT	Straylight contamination is likely
10	CLDICE	Probable cloud or ice contamination (mask)
11	TURBIDW	Turbid water detected
12	HISOLZEN	High solar zenith (set if exceeds 70 degree)
13	HITAU	High tau
14	LOWLW	Very low water-leaving radiance (cloud shadow)
15	CHLFAIL	Derived product algorithm failure
16	NAVWARN	Navigation quality is reduced
17	CLDSHDSTL	Cloud shadow and straylight effects
18	MAXAERITER	Aerosol iterations exceeded max
19	MODGLINT	Moderate sun glint contamination
20	CHLWARN	Derived product quality is reduced
21	ATMWARN	Atmospheric correction is suspect
22	DARKPIXEL	Dark pixels
23	SEAICE	Sea ice flag from ancillary data
24	NAVFAIL	Bad navigation
25	FILTER	Pixel rejected by user-defined filter
26	SEAICE_ANA	Analytical sea ice flag based on radiance
27	NIR_SWITCH	Switch for NIR-based atmospheric correction
28	OCEAN	Ocean pixel

Data Format:
NetCDF-4 output for MSL12

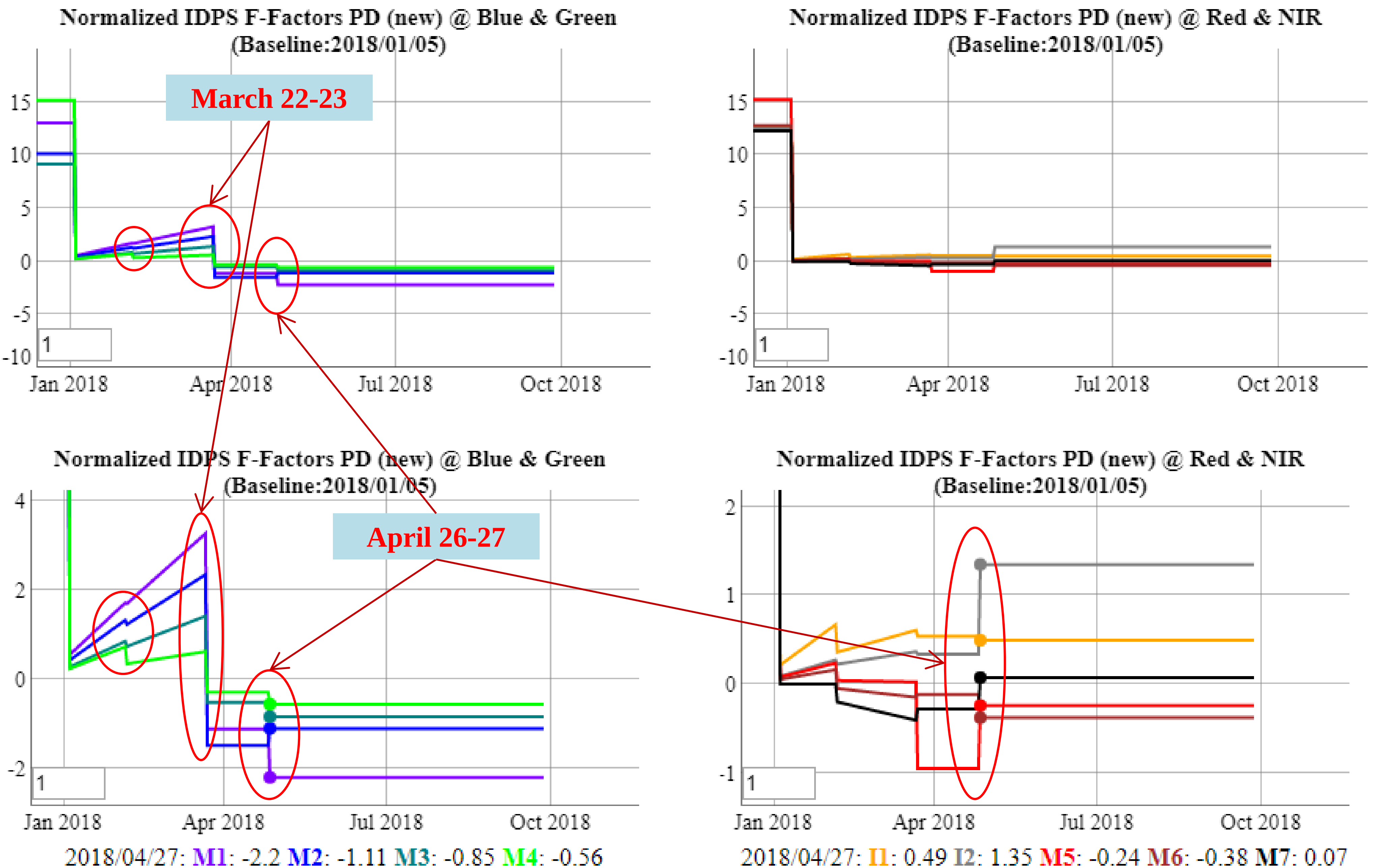
- MSL12 produces L2 file (EDR) in NetCDF4 format for VIIRS-SNPP and VIIRS-NOAA-20.
- The NetCDF4 output is defaulted to be chunked and compressed with deflate level-1, with file size reduced to about 1/4 of the uncompressed size.
- The NetCDF4 output is compliant with NetCDF Climate and Forecast (CF) conventions as well as conventions for Unidata Dataset Discovery.
- All post-process programs have been modified to be compatible with both HDF4 and NetCDF4 L2 files.

Summary of VIIRS Ocean Color EDR Products (NOAA-20 and SNPP)

- **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 (642 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), $K_d(\mathrm{PAR})$
  - **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)
  - 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 SDR before April 27, 2018 has some data quality problems!

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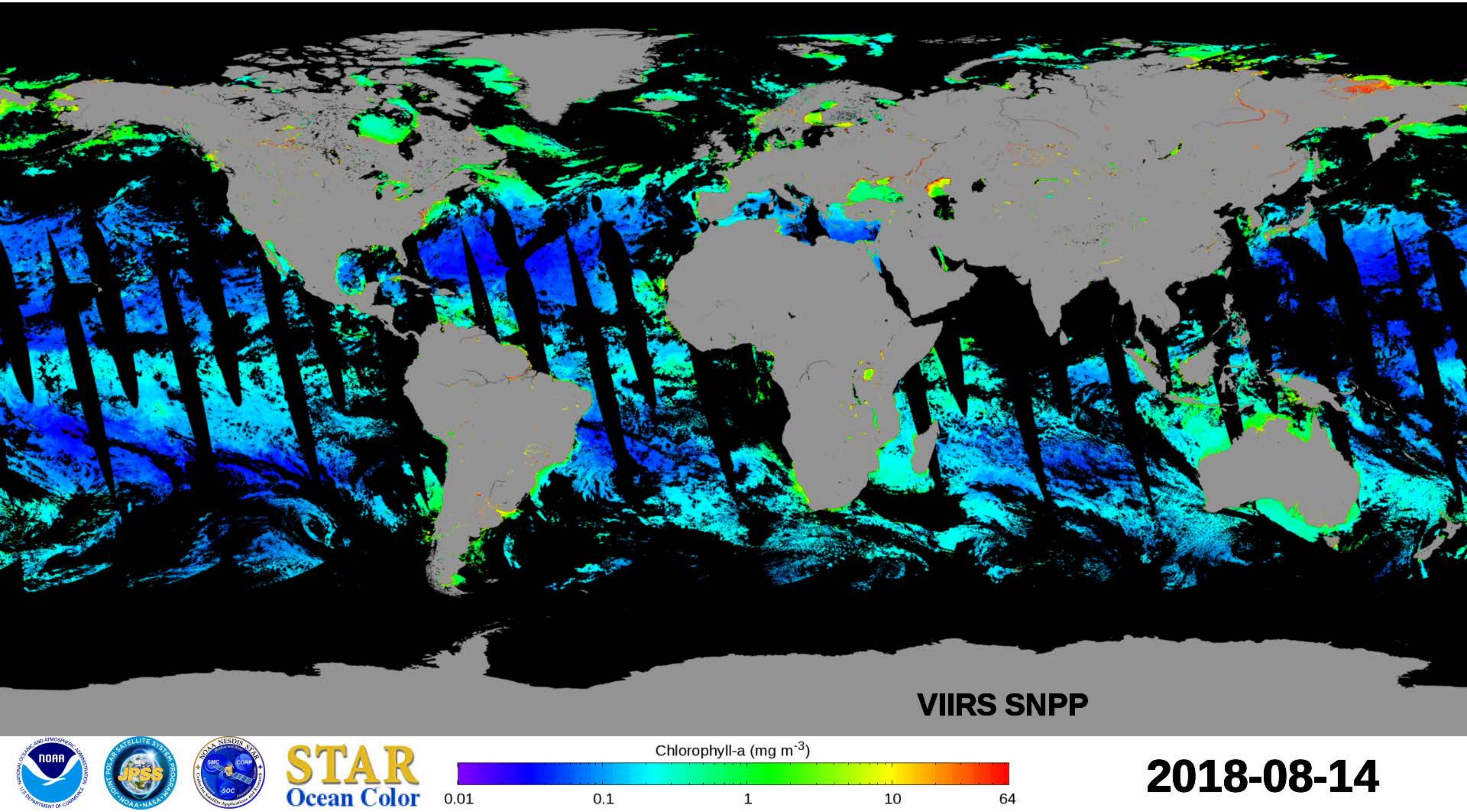
Effort on Producing VIIRS-NOAA-20 Global Ocean Color Products

- The VIIRS Ocean Color EDR team has made very significant effort on producing VIIRS-NOAA-20 ocean color products. 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 mission period.
- After extensive work (for several months), we decided to focus on the time period after April 27, 2018 for producing VIIRS-NOAA-20 ocean color products. With the current VIIRS-NOAA-20 SDR data quality, it is impossible to produce high quality mission-long VIIRS-NOAA-20 ocean color data.
- Due to the lack of high quality MOBY in situ data, we are forced to vicariously calibrate VIIRS-NOAA-20 using the VIIRS-SNPP ocean color products (inter-sensor calibration) over the MOBY Hawaii site.
- In fact, mission-long VIIRS-NOAA-20 ocean color data have been reprocessed several times to have the most optimal vicarious gains for processing VIIRS data, in particular, for the time period after April 27, 2018.
- In addition, because VIIRS-NOAA-20 and VIIRS-SNPP have slightly different spectral band characteristics, a methodology has been developed and implemented in MSL12 to effectively account for the spectral band differences between two VIIRS sensors.

VIIRS-SNPP Global Chl-a
(August 14, 2018)



Global VIIRS-SNPP Chl-a data are routinely produced

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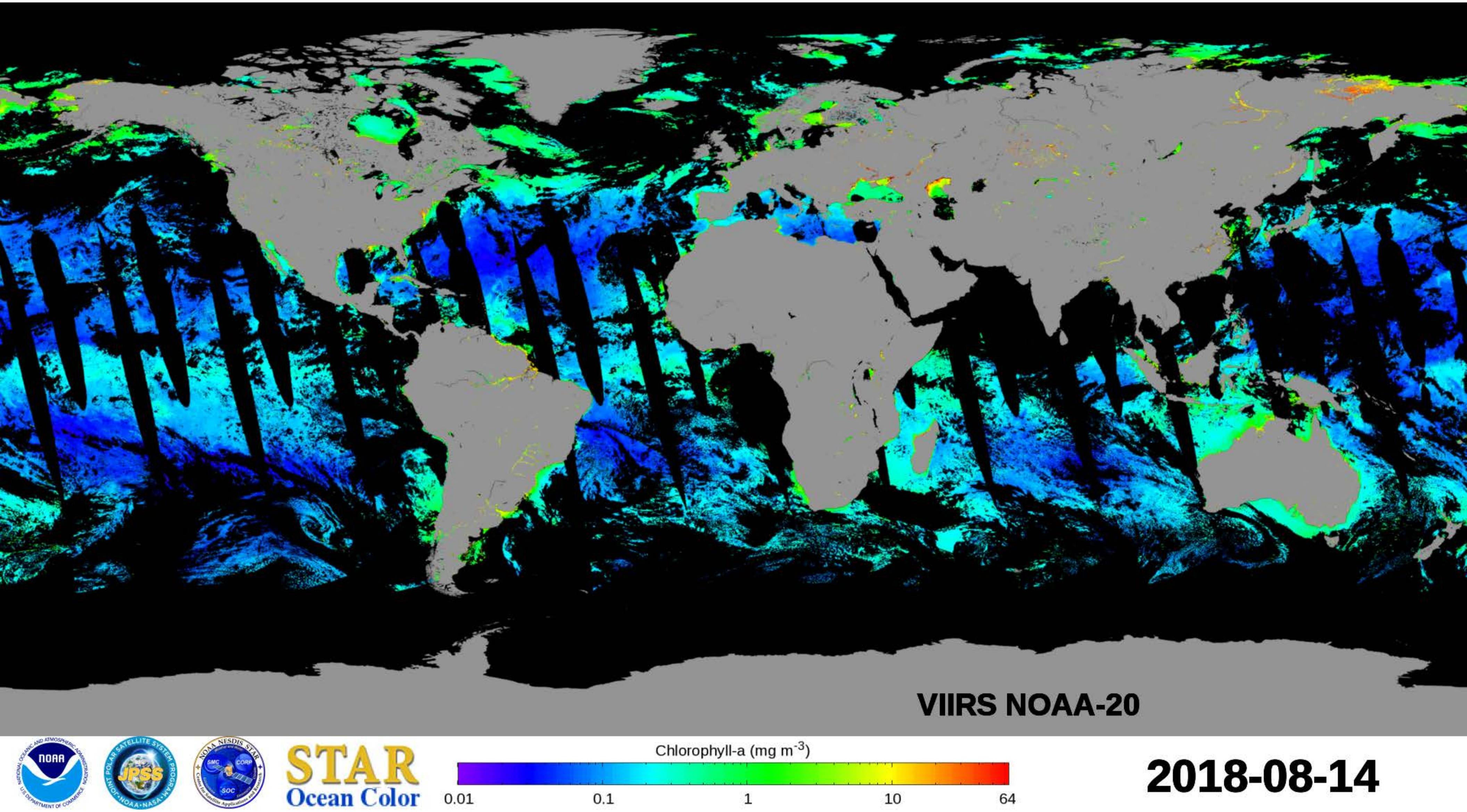
VIIRS-NOAA-20 Global Chl-a

(August 14, 2018)



Global VIIRS-NOAA-20 Chl-a data are routinely produced

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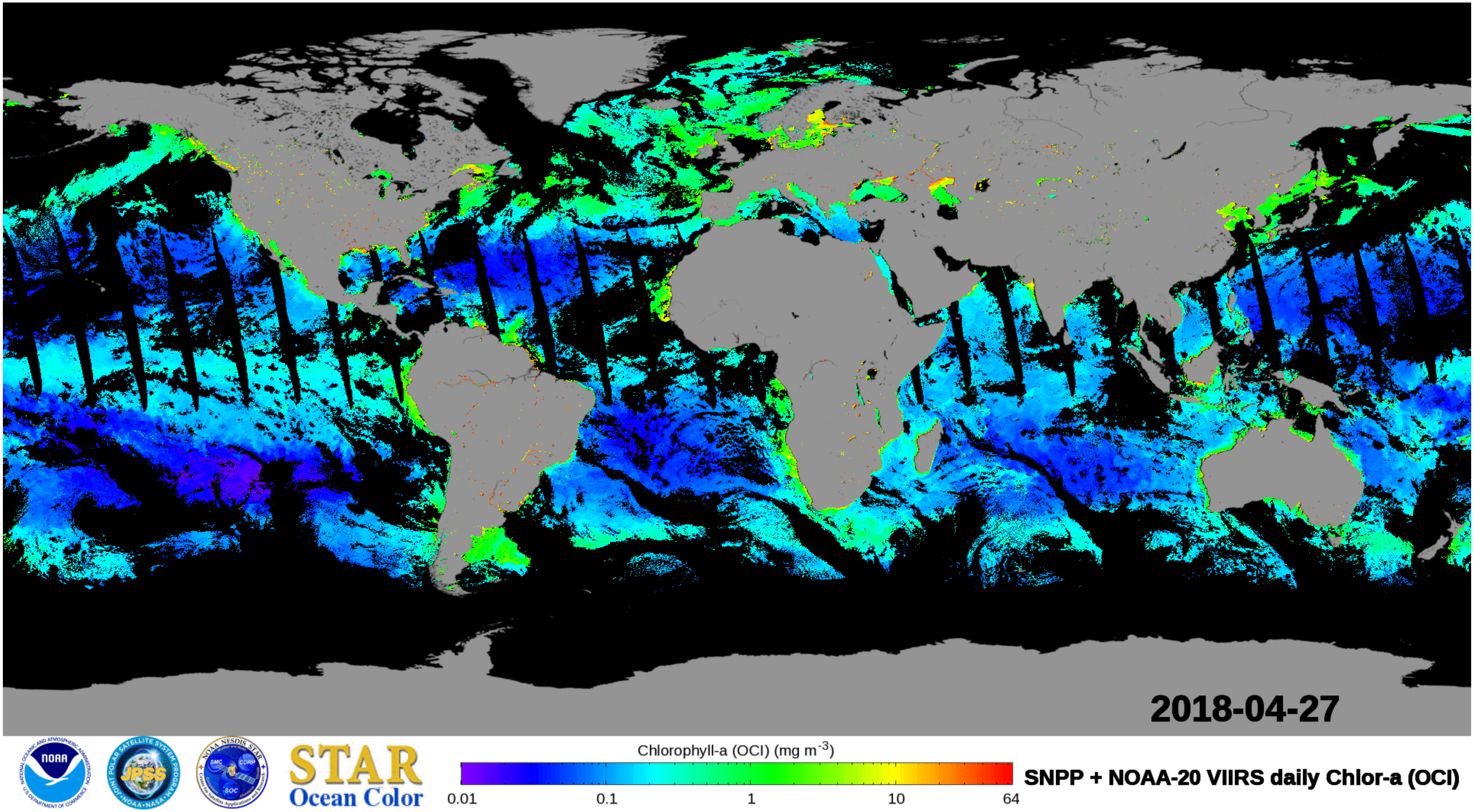
VIIRS-SNPP and NOAA-20 Merged Chl-a Images

(April 27-October 31, 2018)



Global VIIRS merged Chl-a from SNPP/NOAA-20 are routinely produced

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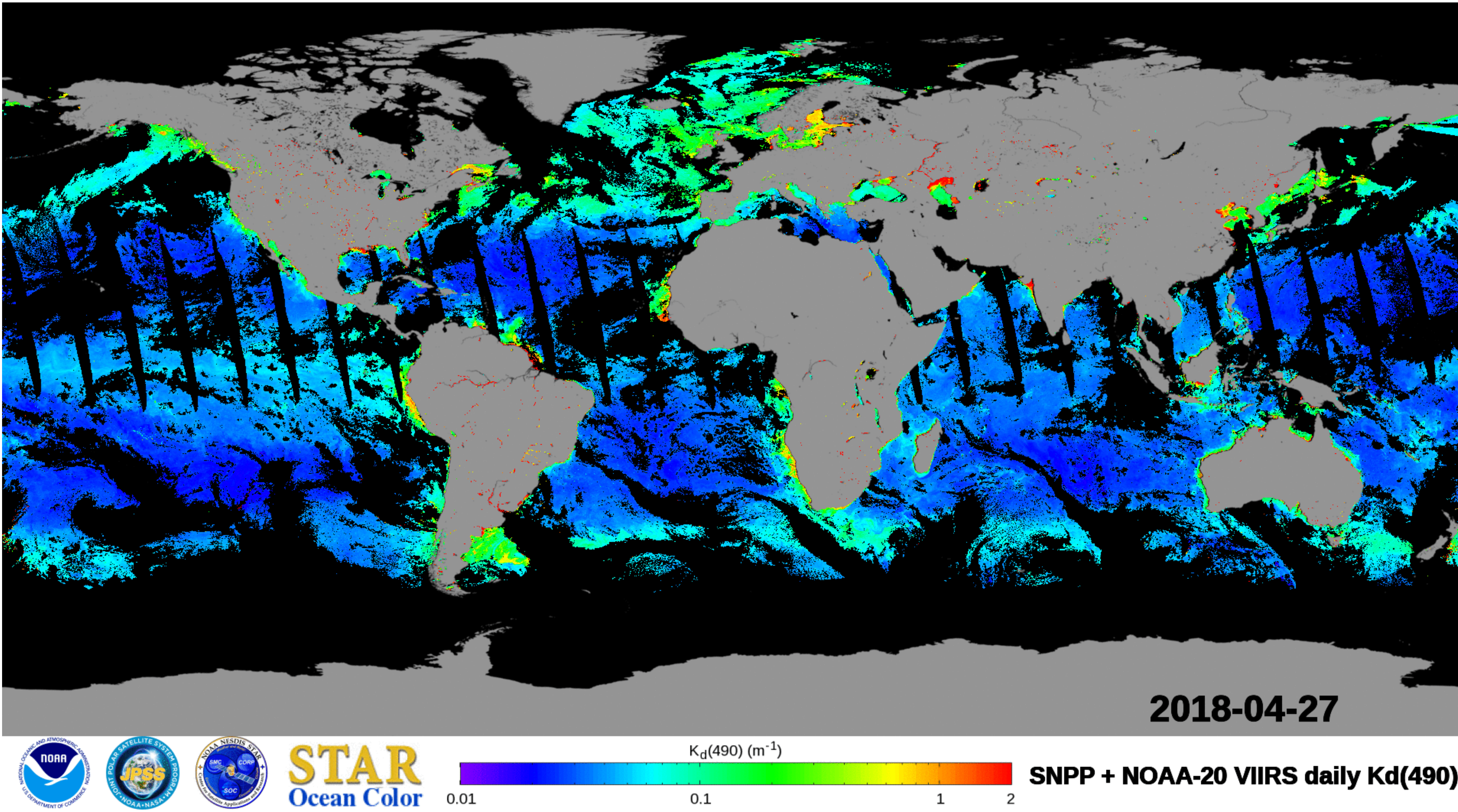
VIIRS-SNPP and NOAA-20 Merged K_d(490) Images

(April 27-October 31, 2018)



Global VIIRS merged K_d(490) from SNPP/NOAA-20 are routinely produced

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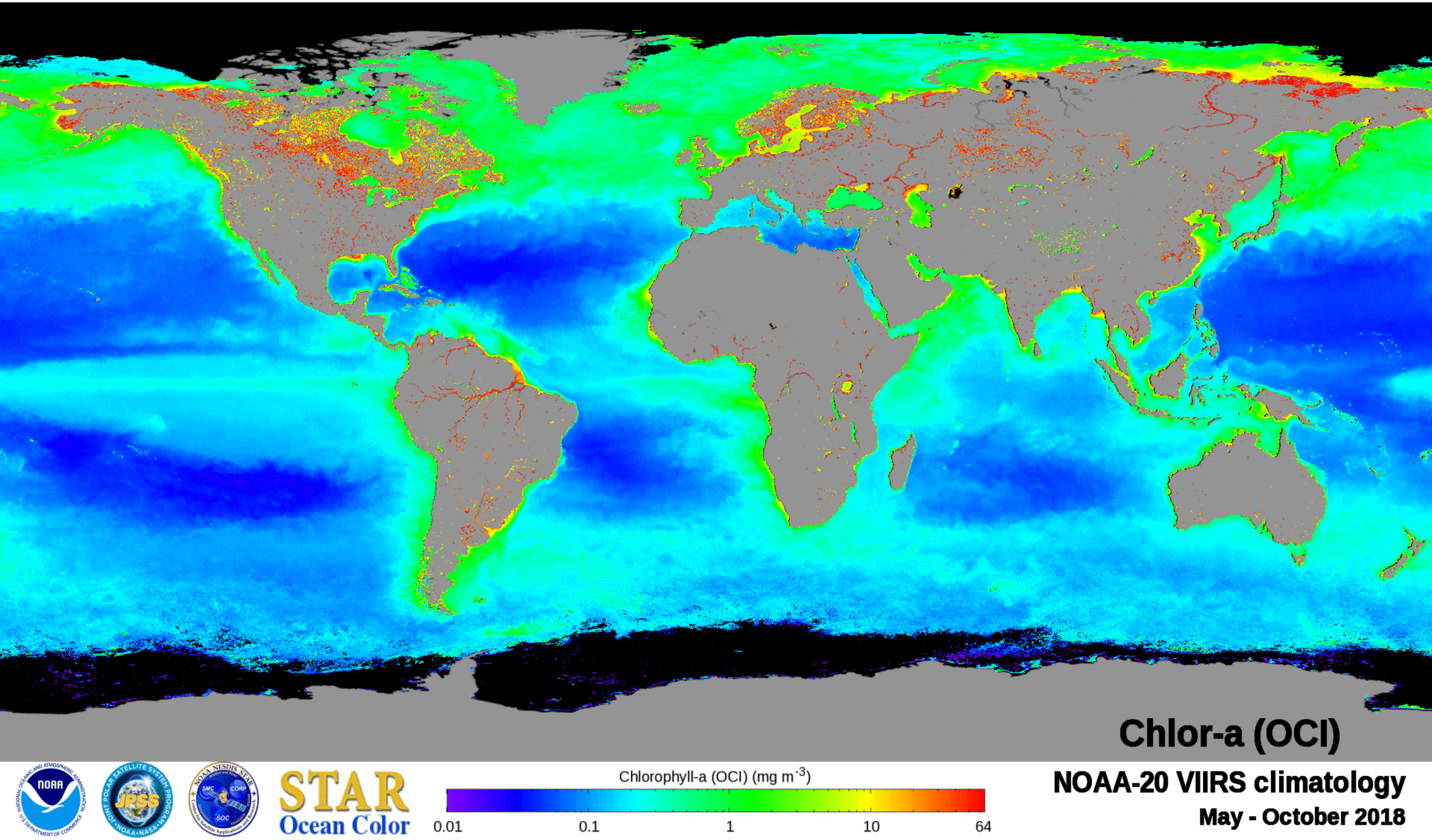
VIIRS Climatology Ocean Color Product Image

NOAA-20 (May–October 2018)



MSL12 with the NIR-SWIR data processing system is used for VIIRS

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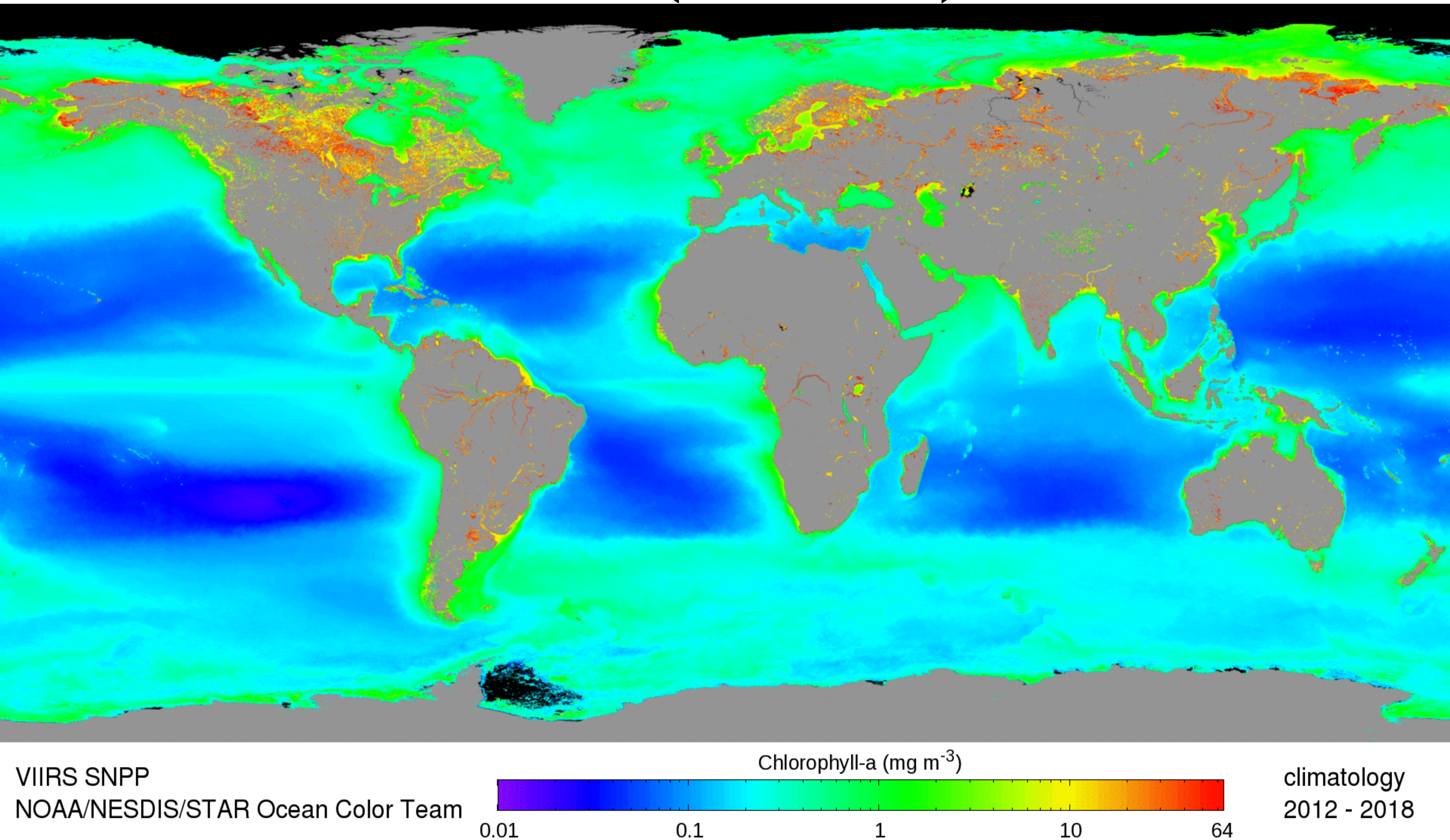
VIIRS Climatology Ocean Color Product Image

SNPP (2012–2018)



MSL12 with the NIR-SWIR data processing system is used for VIIRS

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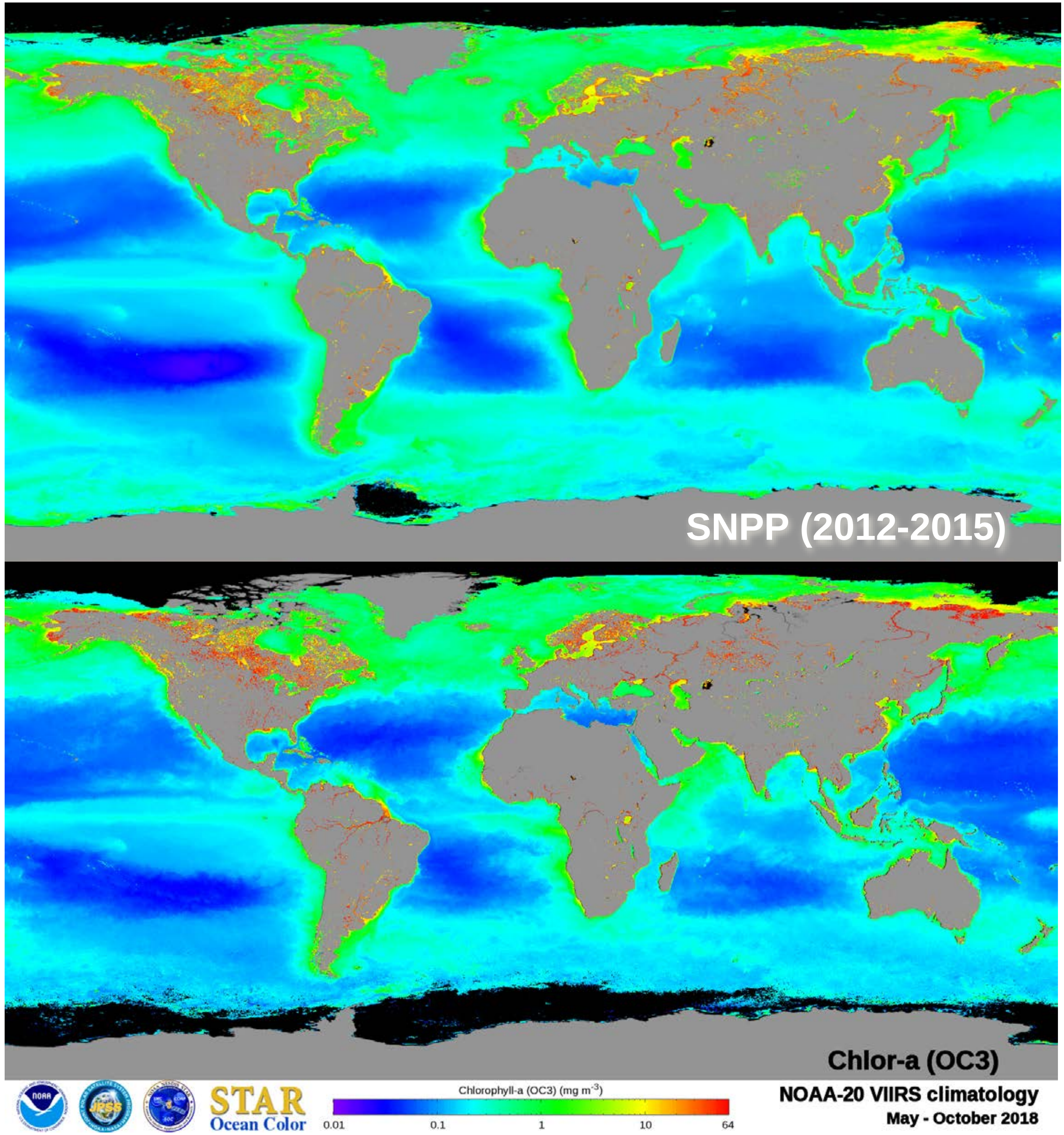
Climatology Chl-a from VIIRS-SNPP and VIIR-NOAA-20



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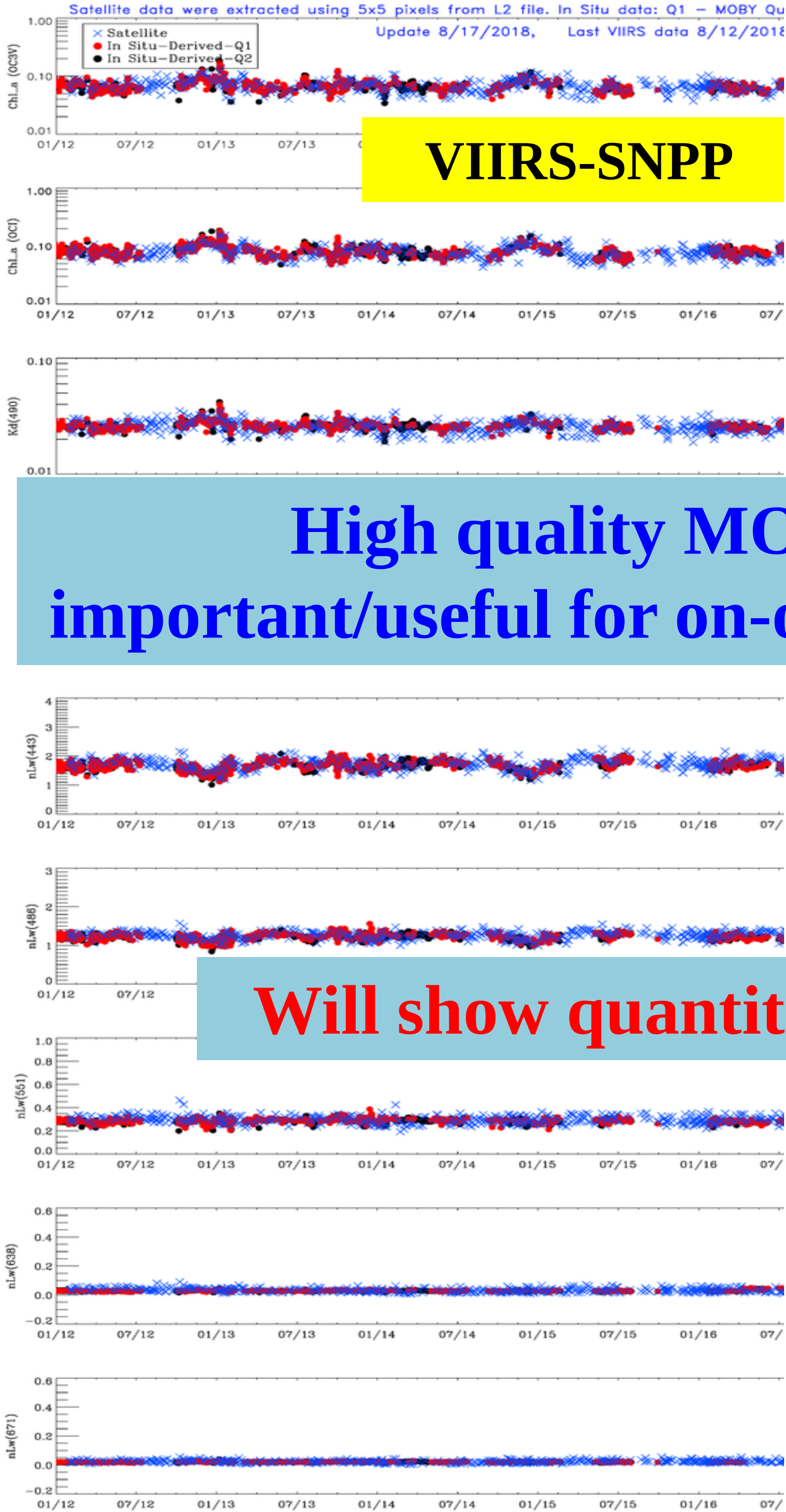
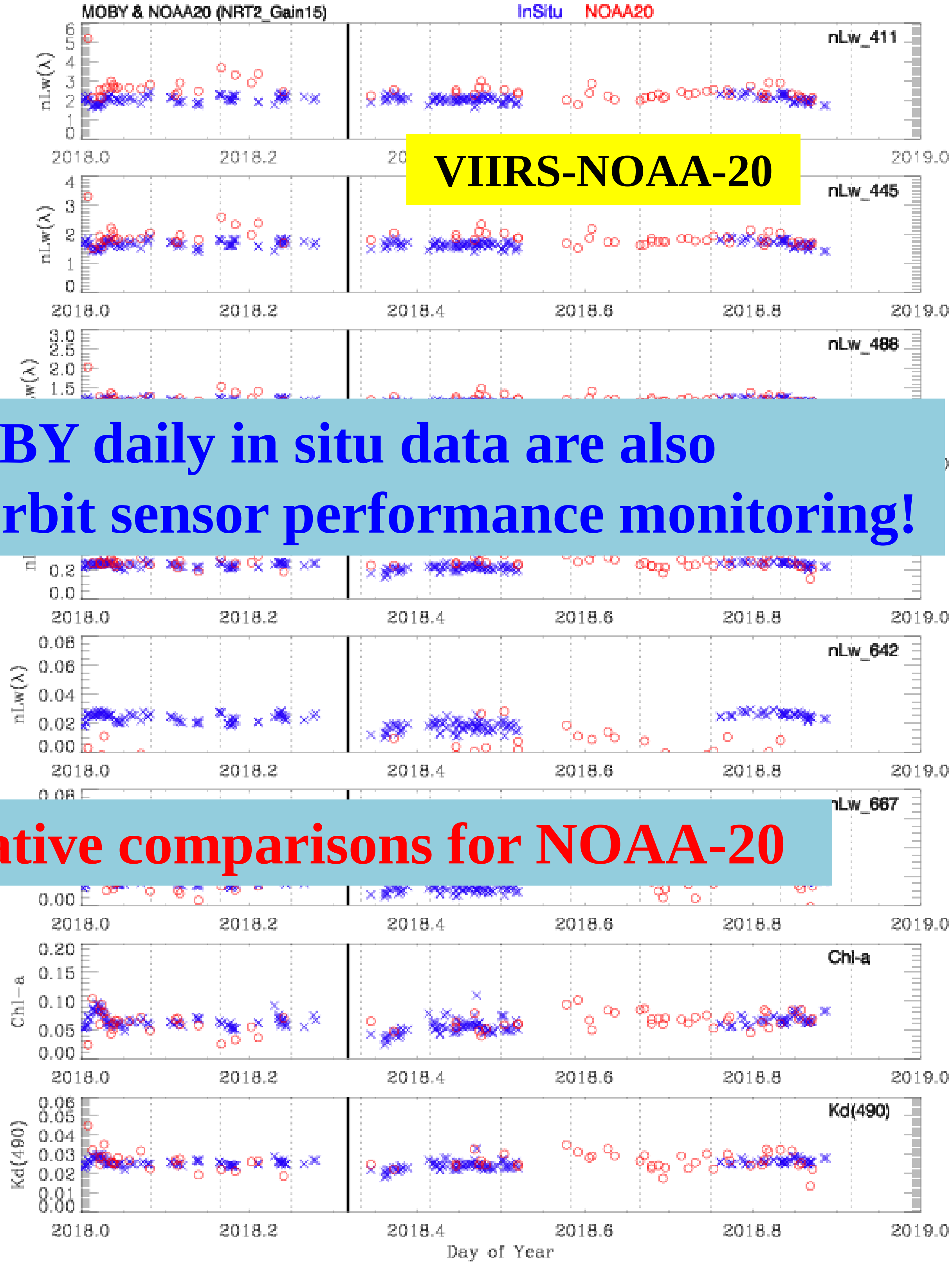
Requirement Check List – Ocean Color/Chlorophyll

JERD	Requirement	Meet Requirement (Y/N)?
JERD-2128	The algorithm shall produce an OC/C product during clear conditions	
JERD-2129	The algorithm shall produce an OC/C product during daytime conditions	
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)	
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)	
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
(NOAA-20 compared with **MOBY in situ data**)

- 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 water).
- MOBY in situ data have high data quality and considered as “truth”. However, there are limited in situ data available for VIIRS-NOAA-20 period due to various MOBY instrument issues.
- Using the limited MOBY in situ data (high quality 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 after **April 27, 2018** VIIRS-NOAA-20 ocean color data compared well with MOBY in situ measurements and have high data quality. It is also shown that before **April 27, 2018** VIIRS-NOAA-20 ocean color data have some data quality issues due to SDR calibration problems.
- Results show strong spectral correlation for the errors in VIIRS-NOAA-20-derived normalized water-leaving radiance spectra.





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 Timeseries of

MOBY In Situ

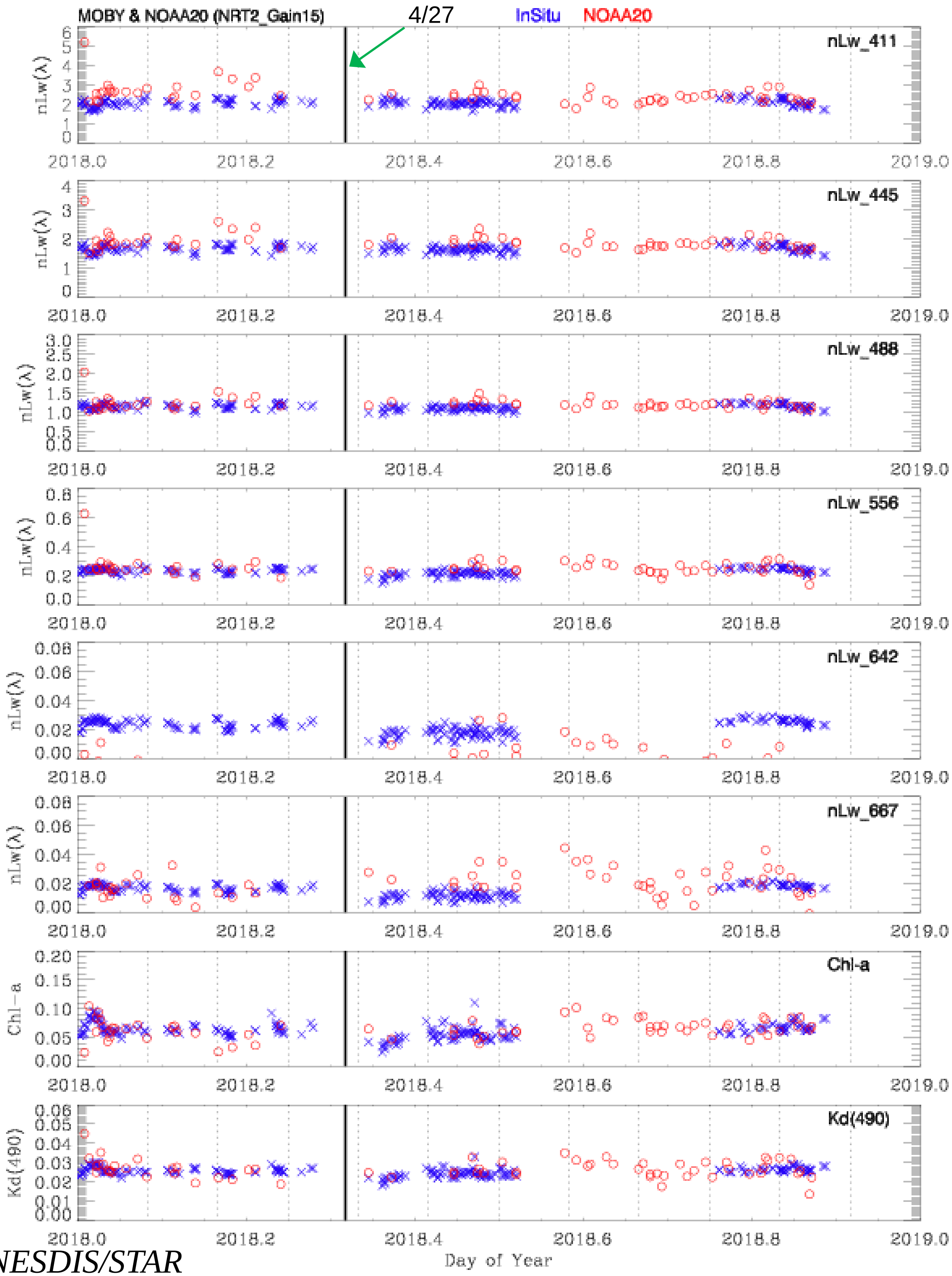
&

VIIRS NOAA-20

NRT2 Gain15

(5x5 extraction around MOBY site)

MOBY



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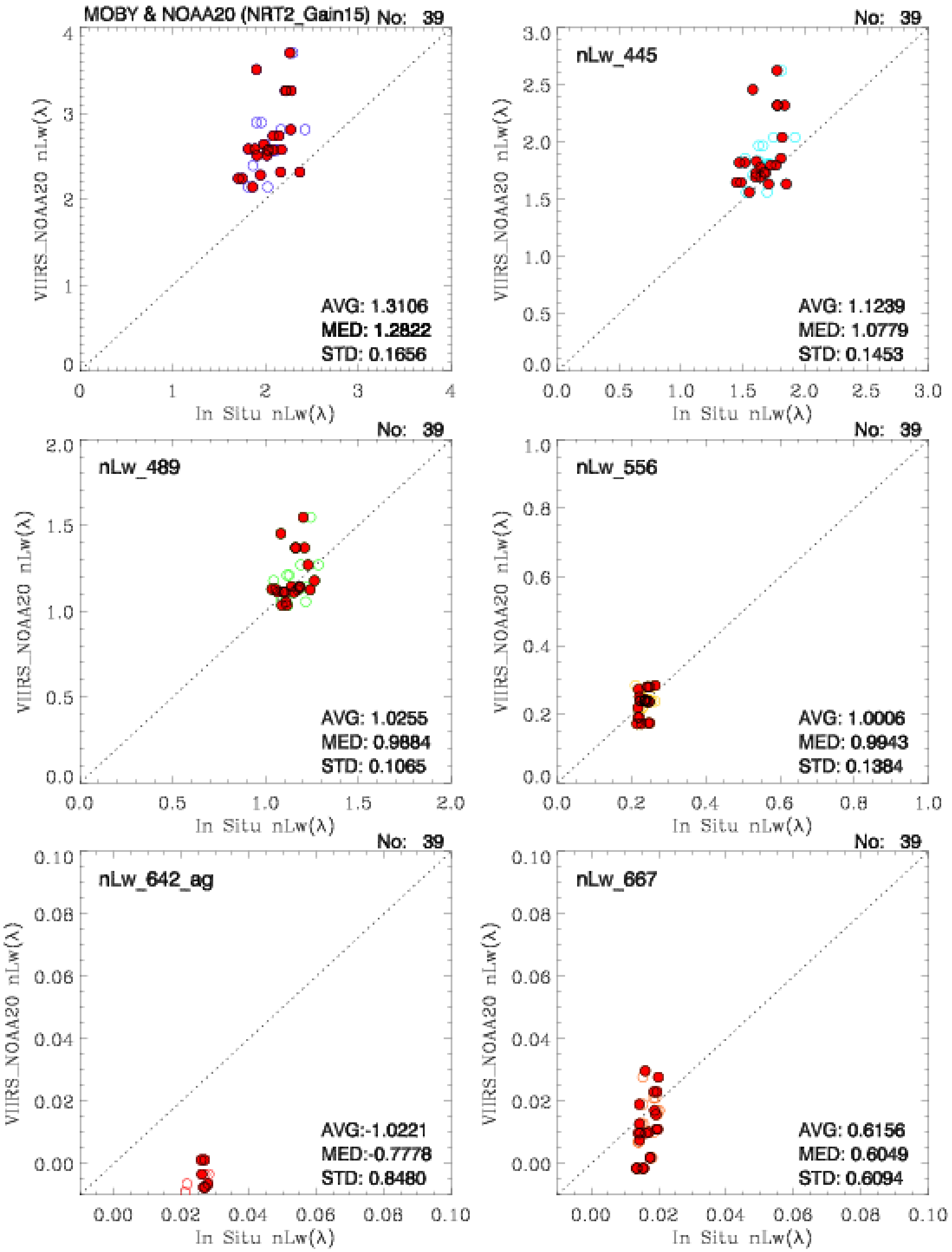
Before April 27

MOBY

Matchup of
MOBY In Situ
&
VIIRS NOAA-20
NRT Gain15



Within +/- 3 hours
Q1+Q2
[2018-1/7 ~ 4/26]

*. red-filled circles are **Q1**

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Before April 27

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

*. MOBY Q1 only

	VIIRS NOAA20 NRT2 Gain15 (2018-01/07 ~ 04-26)							
	RATIO (SAT/ENV)				DIFFERENCE (SAT-ENV)			
	AVG	MED	STD	No	AVG	MED	STD	%Diff
***nL*$_w$(411)**	**1.3184**	1.2822	0.182	23	**0.6477**	0.5498	0.3787	31.667
***nL*$_w$(445)**	**1.1352**	1.0843	0.162	23	**0.2240**	0.1382	0.2745	13.446
***nL*$_w$(489)**	**1.0387**	1.0064	0.115	23	**0.0432**	0.0071	0.1324	3.774
***nL*$_w$(556)**	**0.9870**	1.0136	0.145	23	**-0.0030**	0.0032	0.0339	-1.289
***nL*$_w$(667)**	**0.5150**	0.5906	0.690	23	**-0.0078**	-0.0068	0.0116	-47.030

*. Including all pixels < -0.1

*. %Diff (%)= 100 * (Mean_DIFFERENCE / Mean_ENV)

***. 4 L2_flags, <+/-3 hours**

After April 27

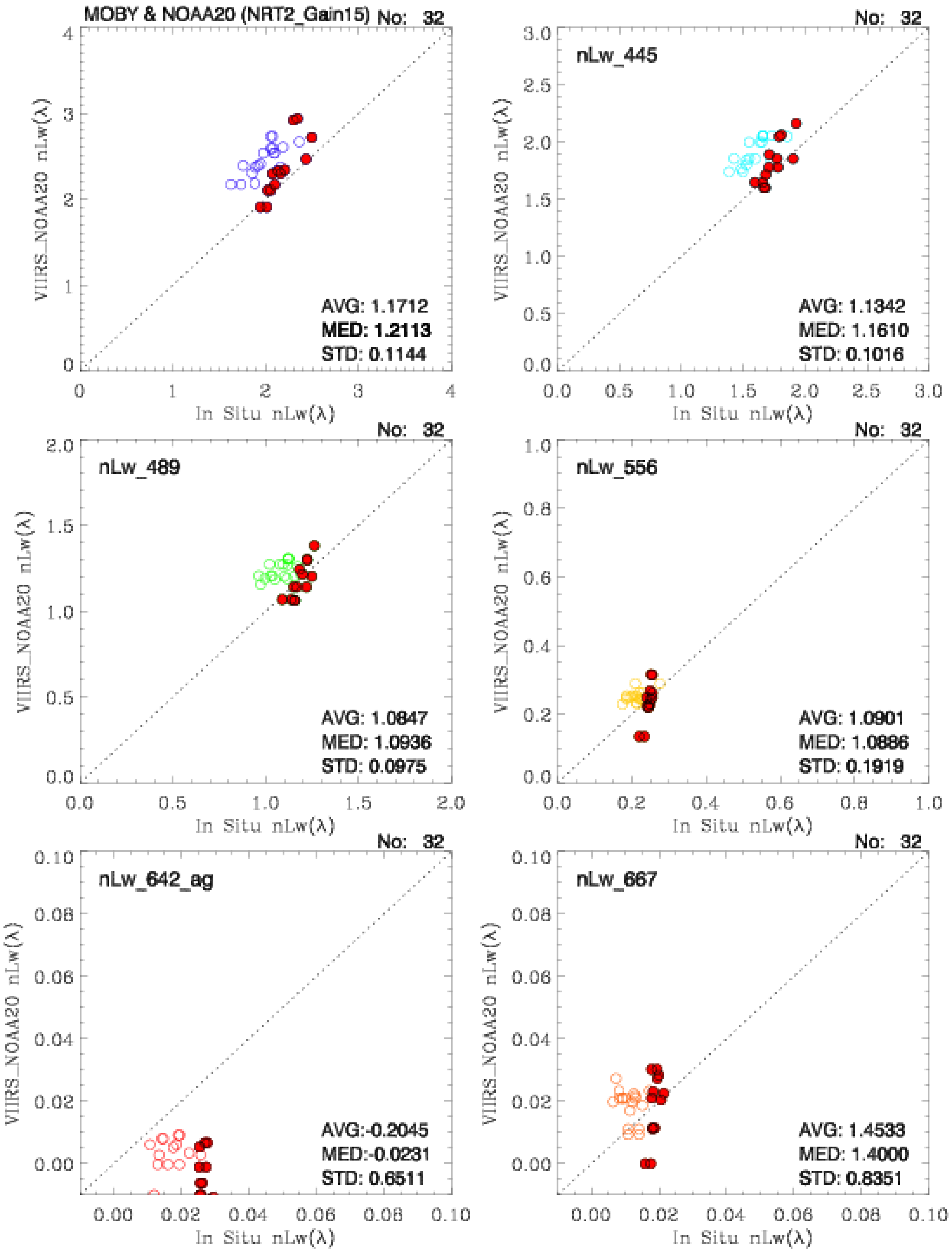
Matchup of

MOBY In Situ

&

VIIRS NOAA20

NRT Gain15



MOBY

Within +/- 3 hours

Q1+Q2

[2018-4/27 ~ now]

*. red-filled circles are **Q1**

After April 27

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

*. MOBY Q1 only

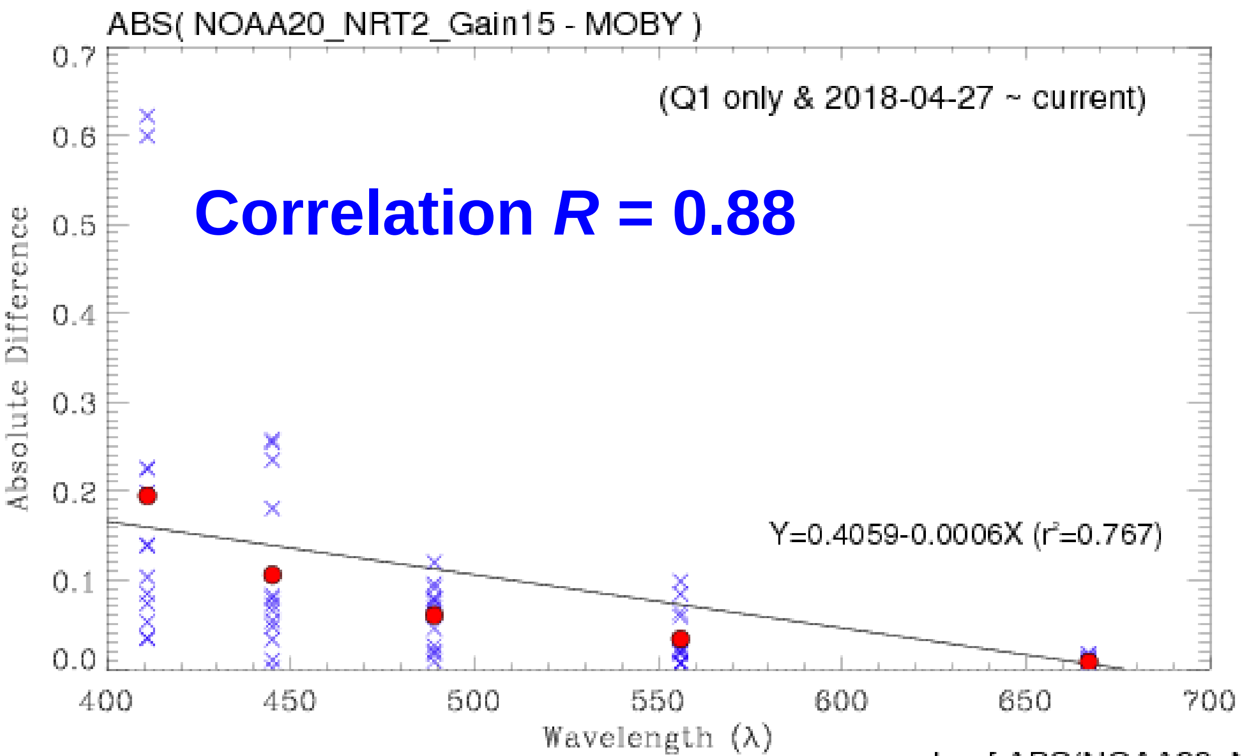
	VIIRS NOAA-20 (2018-04-27 ~ Current)							
	RATIO (SAT/ENV)				DIFFERENCE (SAT-ENV)			
	AVG	MED	STD	No	AVG	MED	STD	%Diff
$nL_w(411)$	**1.0765**	1.0627	0.094	13	**0.1736**	0.1382	0.2164	7.991
$nL_w(445)$	**1.0413**	1.0340	0.067	13	**0.0744**	0.0541	0.1213	4.268
$nL_w(489)$	**0.9936**	0.9814	0.059	13	**-0.0063**	-0.0202	0.0715	-0.528
$nL_w(556)$	**0.9545**	0.9728	0.195	13	**-0.0097**	-0.0068	0.0462	-3.960
$nL_w(667)$	**0.9546**	1.0514	0.551	13	**-0.0005**	0.0011	0.0097	-2.549

*. Including all pixels < -0.5

*. %Diff (%)= 100 * (Mean_DIFFERENCE / Mean_ENV)

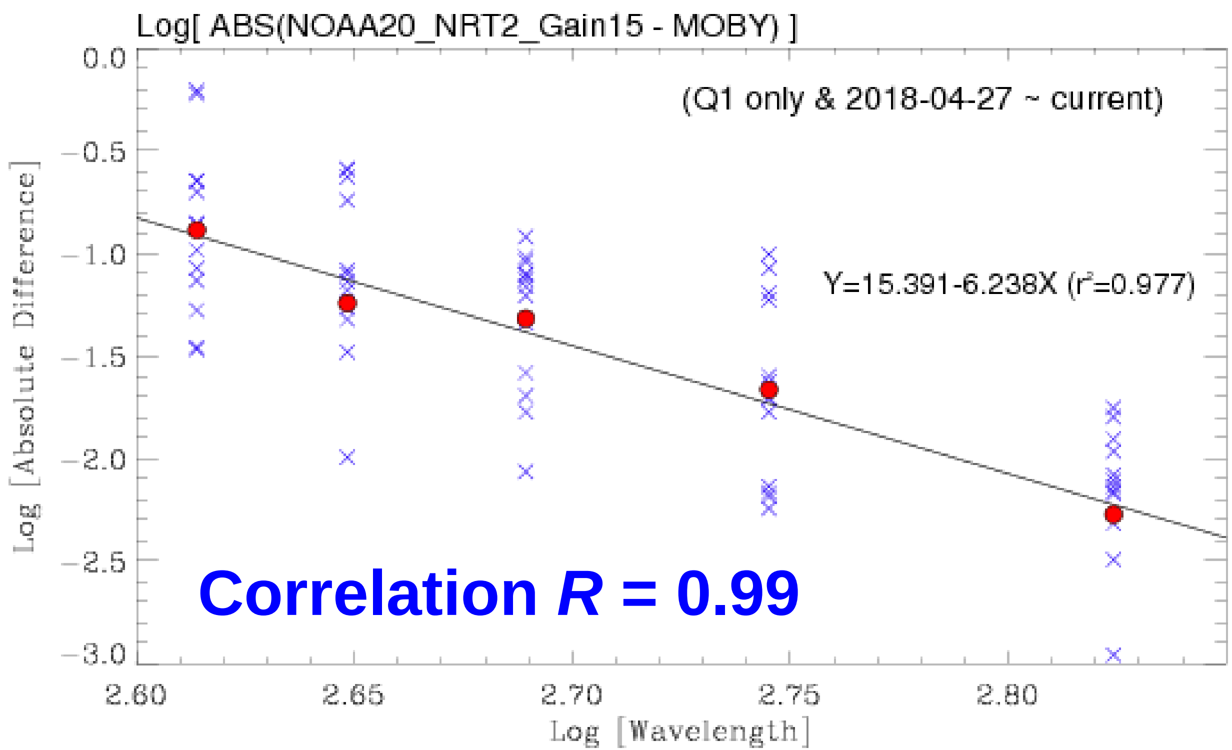
*. **4 L2_flags, <+/-3 hours**

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



Within +/- 3 hours & **Q1 only**
[2018-4/27 ~ now]

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



Results show strong spectral correlation in nL_w errors!

After April 27

Ocean Color Data Performance Evaluation
(NOAA-20 compared with SNPP)

- 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/index.php).
- In fact, the merged global daily Chl-a data from VIIRS-SNPP and VIIRS-NOAA-20 have been routinely produced, showing improved (e.g., coverage) and consistent results, e.g., no observable artifacts.
- 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.
- Our evaluation results show that after **April 27, 2018** VIIRS-NOAA-20 ocean color data quality meets the data Provisional (or even Validated) requirements. It is also determined that before **April 27, 2018** VIIRS-NOAA-20 ocean color data have some data quality issues due to the SDR calibration problems.

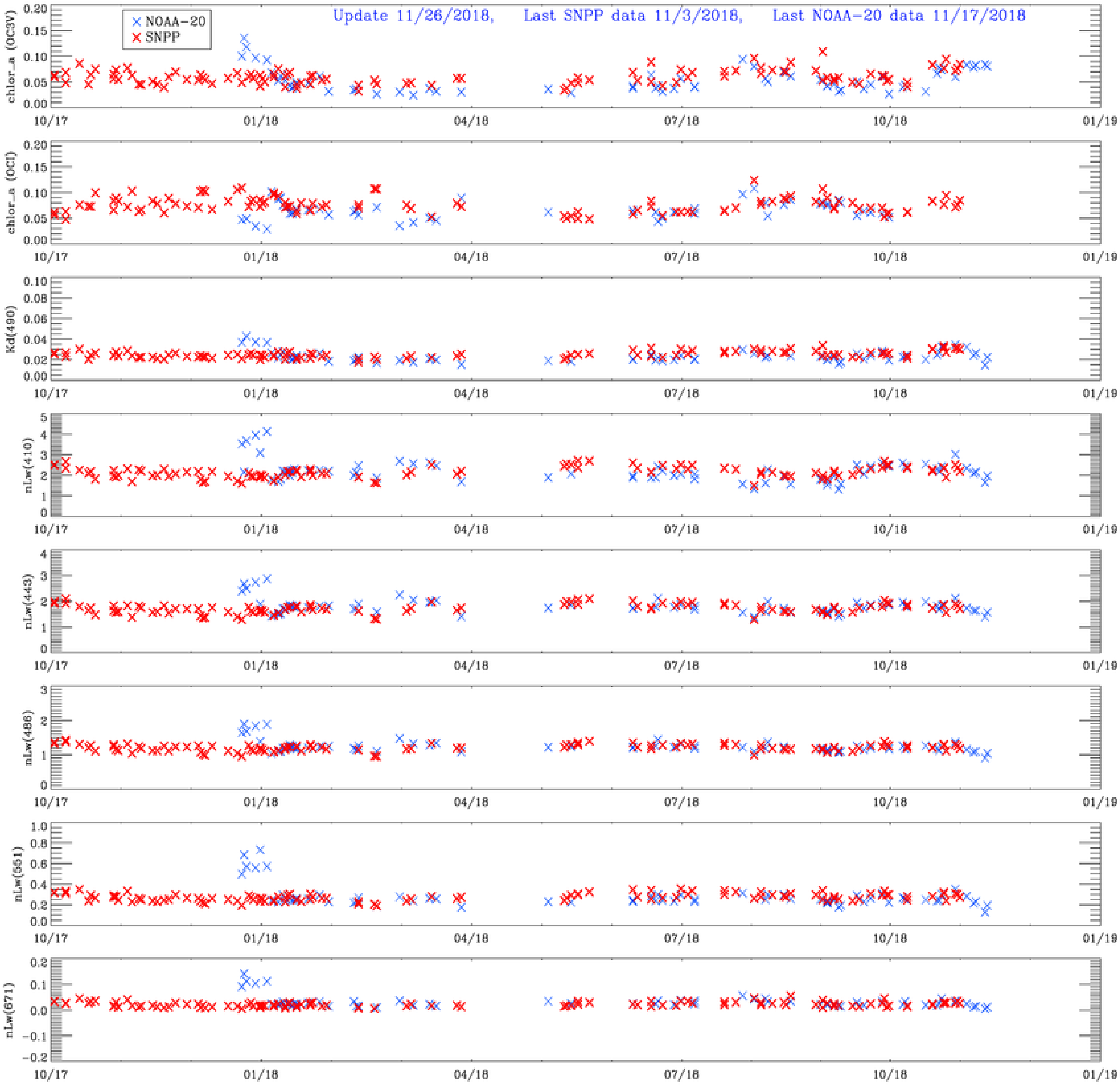
Matchup Timeseries of

VIIRS NOAA-20

vs.

VIIRS-SNPP

At MOBY Site



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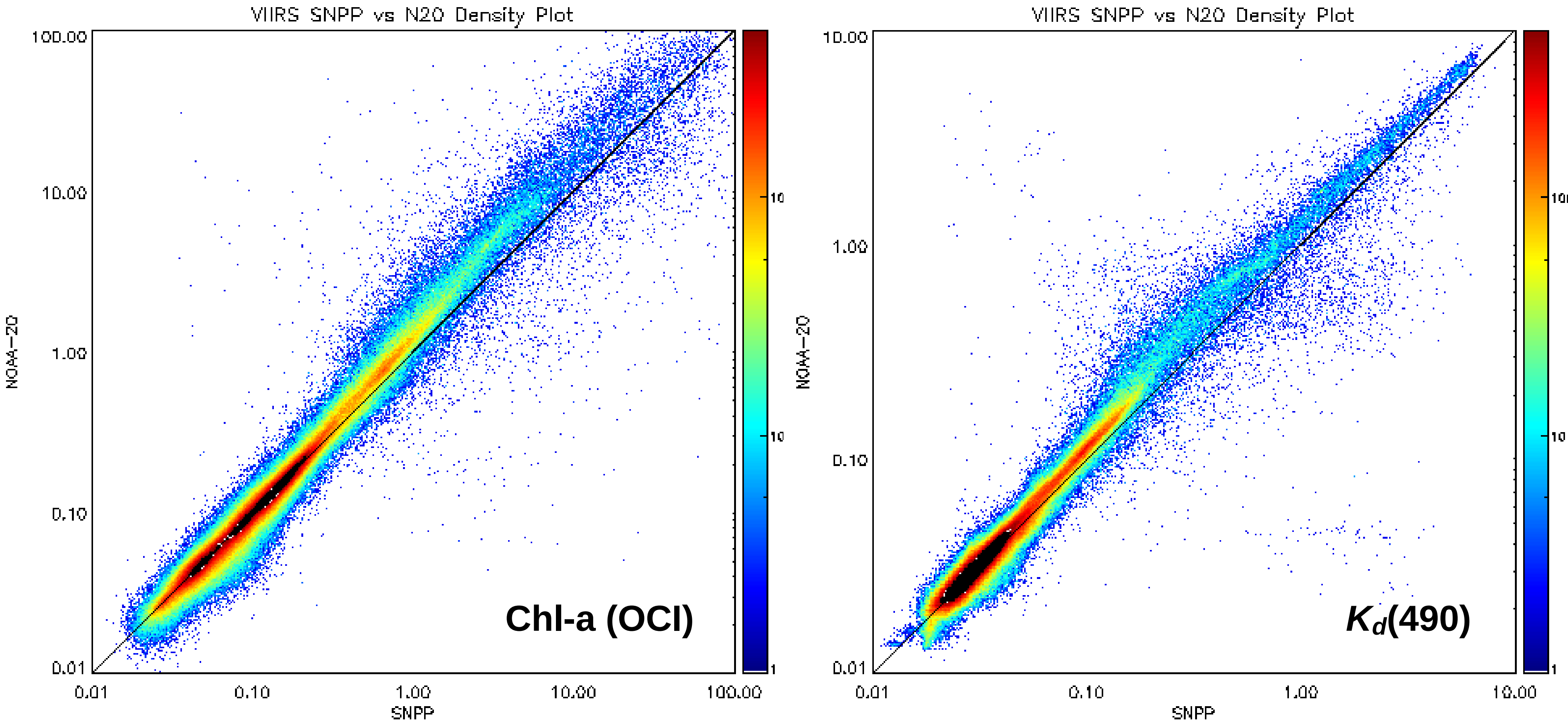
OC Performance: Chl-a & K_d(490)
(NOAA-20 Compared with SNPP)



Global Data on June 1, 2018 for All the data

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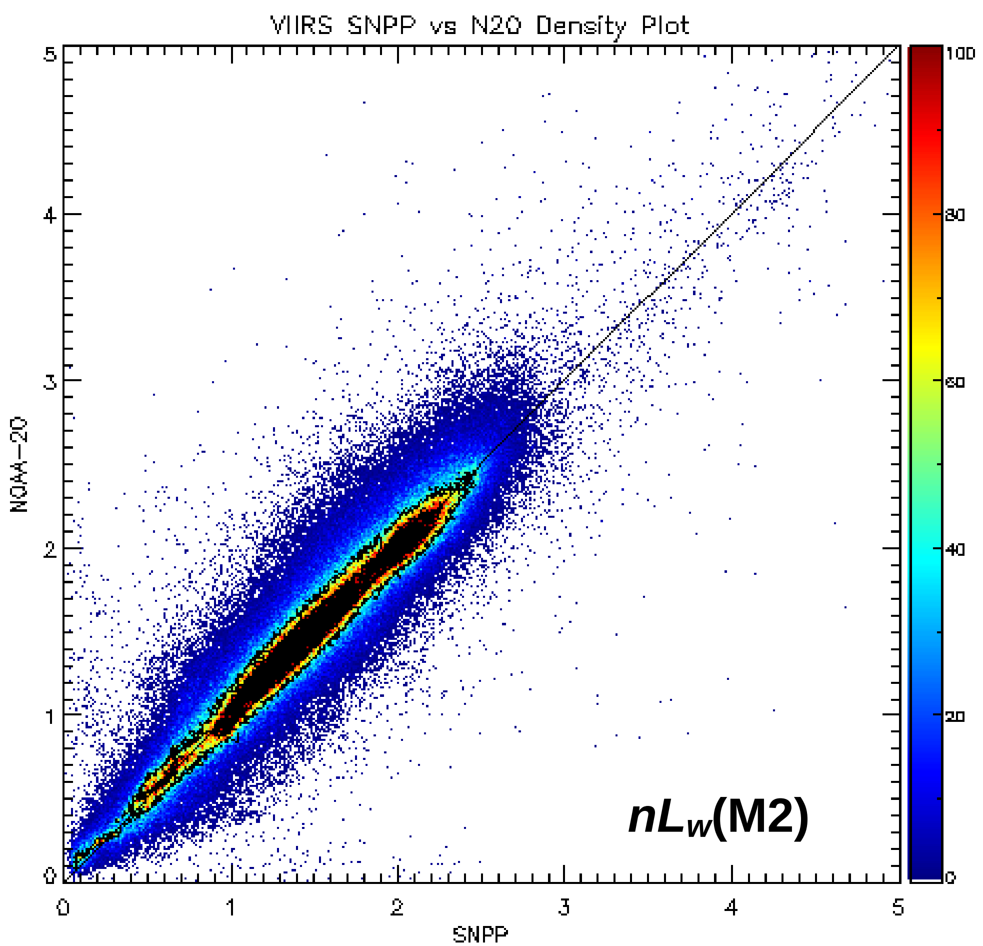
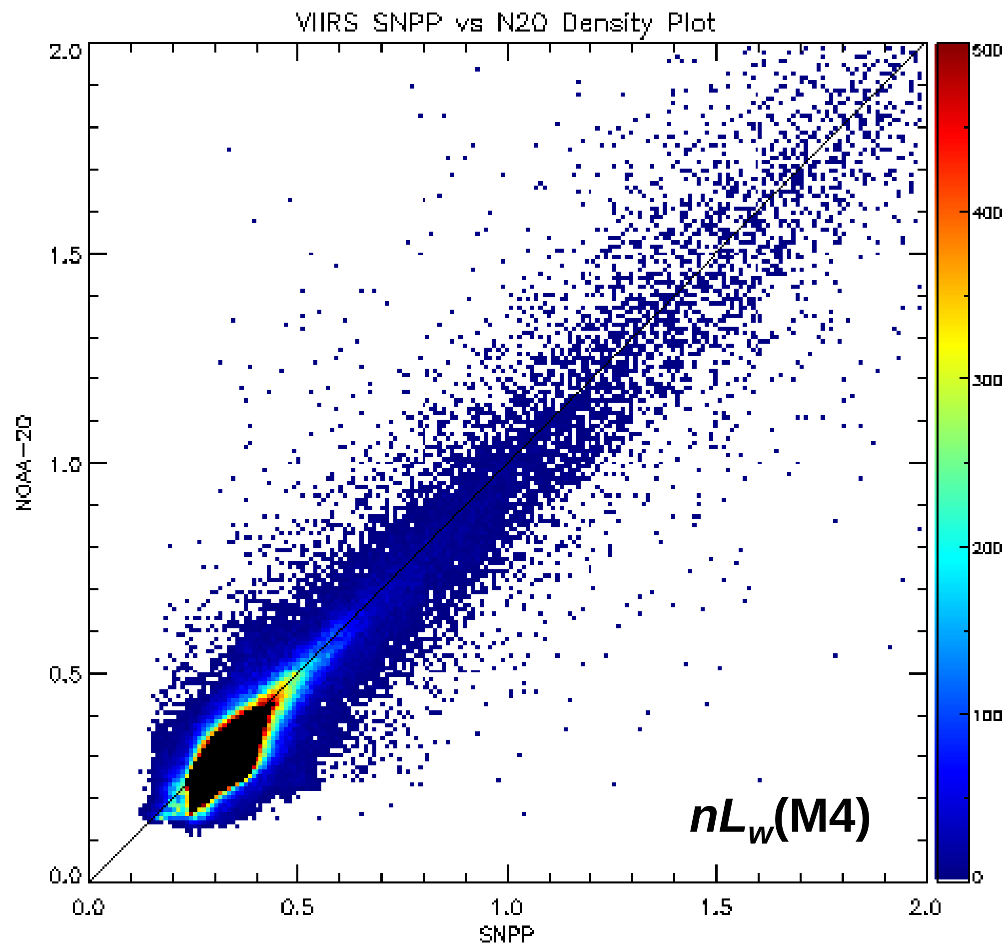
OC Performance: nL_w(M2) & nL_w(M4)
(NOAA-20 Compared with SNPP)





Global Data on June 1, 2018 for All the data

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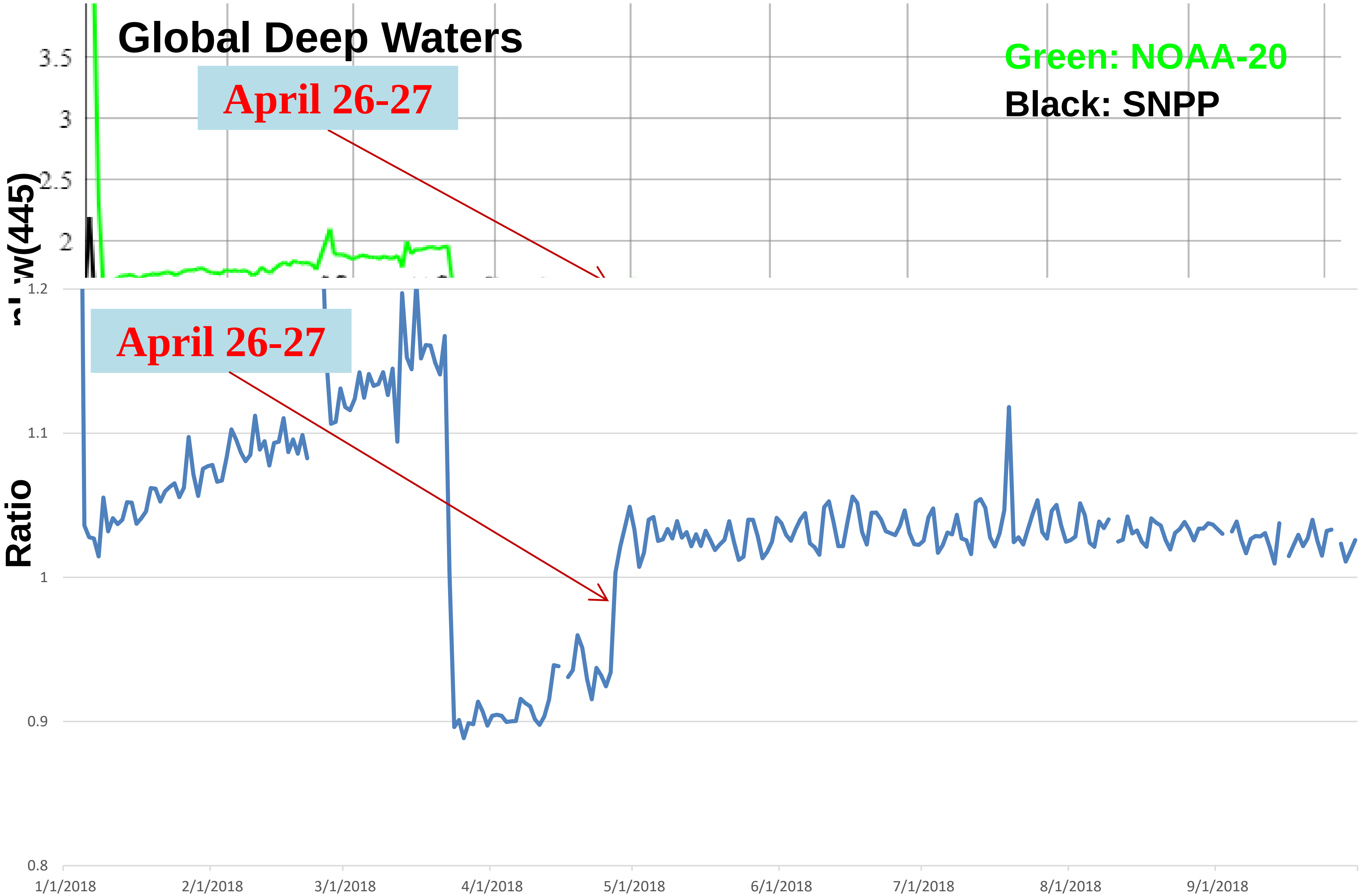
Global $nL_w(445)$ (Blue band) Performance

(NOAA-20 Compared with SNPP)



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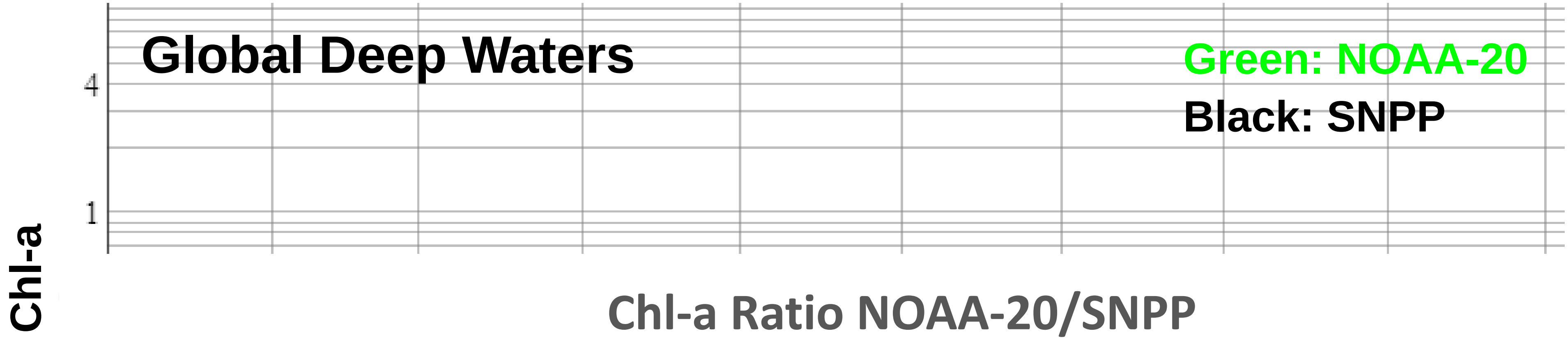
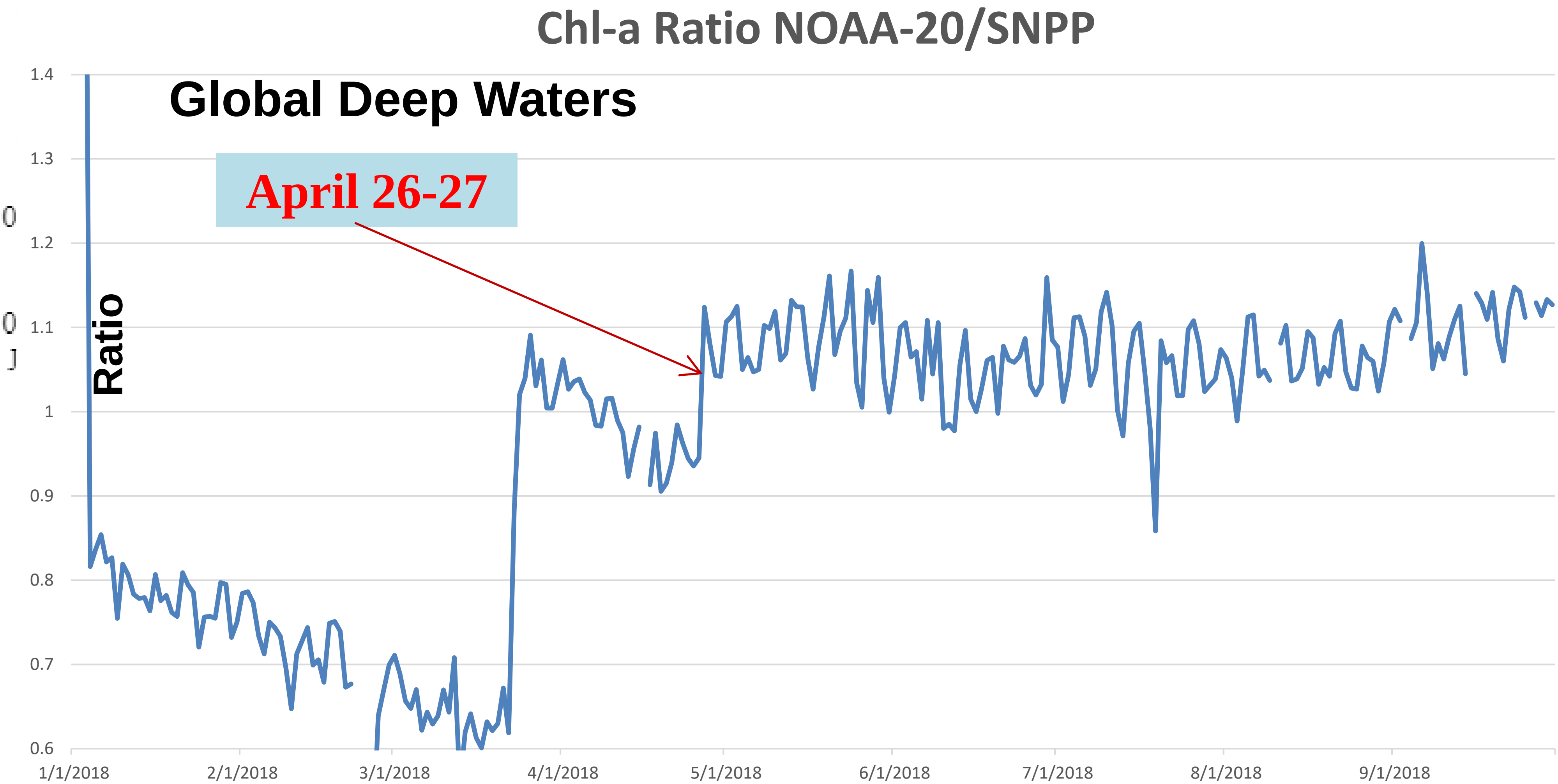
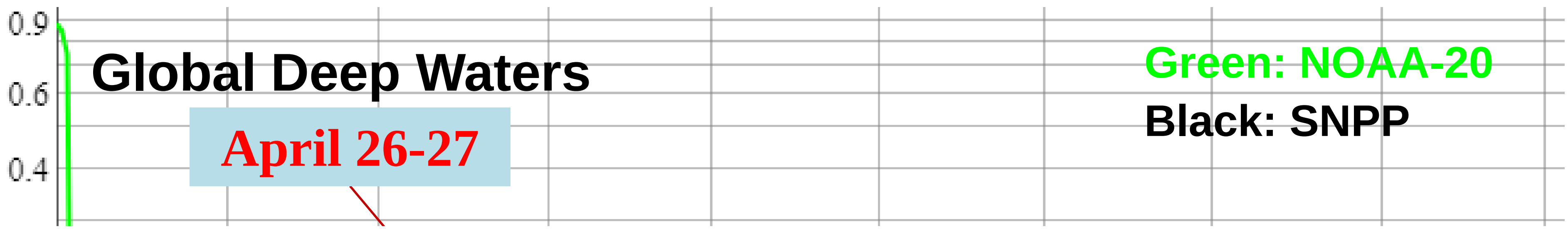
Global Chl-a Performance
(NOAA-20 Compared with SNPP)

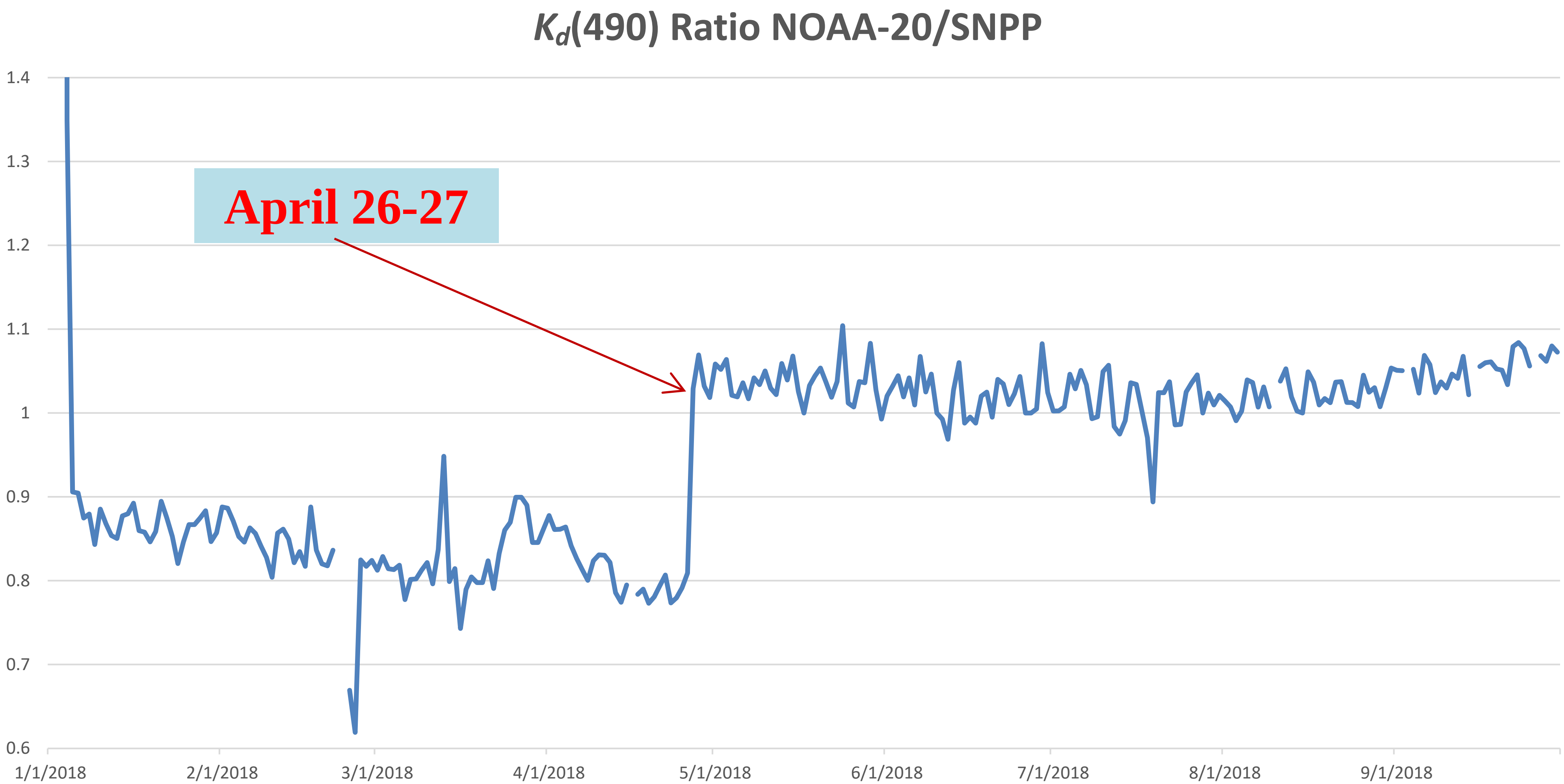




Menghua Wang, NOAA/NESDIS/STAR

Global K_d(490) Performance
(NOAA-20 Compared with SNPP)





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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)
Before April 27	1.0526	1.0450	1.0802	1.0652	1.1197	1.0970
After April 27	**1.0294**	**1.0291**	**1.0314**	**1.0301**	1.0353	1.0337

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)
Before April 27	0.1689	0.2483	0.3510
After April 27	**0.0102**	**0.0125**	0.0237

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

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)
Before April 27	0.9572	0.8319	0.8333	0.7757	0.7024	0.7121
After April 27	**0.9602**	**0.9606**	**1.0730**	**1.0712**	1.4692	1.4992

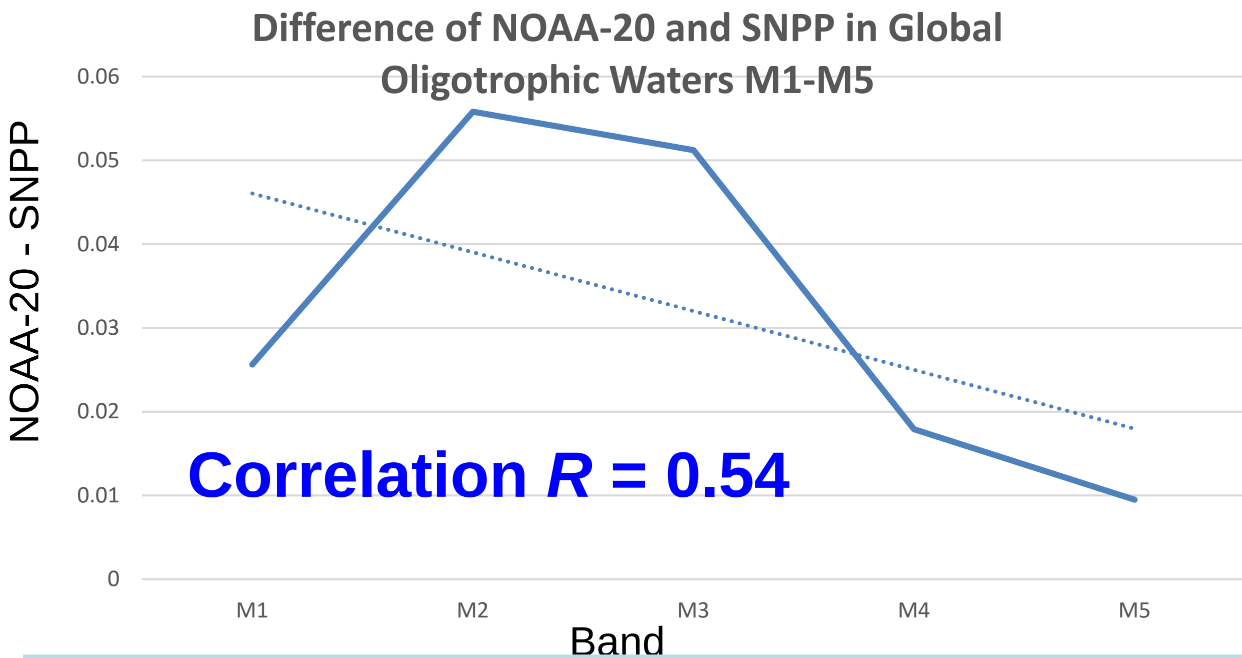
Precision: Standard Deviation (STD) of **Chl-a** NOAA-20/SNPP Ratio

Dates	Global Oligotrophic Waters	Global Deep Waters	Global Coastal/Inland Waters
Parameter (Requirement)	**STD** (30%)	**STD** (30%)	**STD** (N/A)
Before April 27	0.6300	0.2575	0.0982
After April 27	**0.0296**	**0.0477**	0.1195

VIIRS-NOAA-20 Chl-a Meets the Requirements!

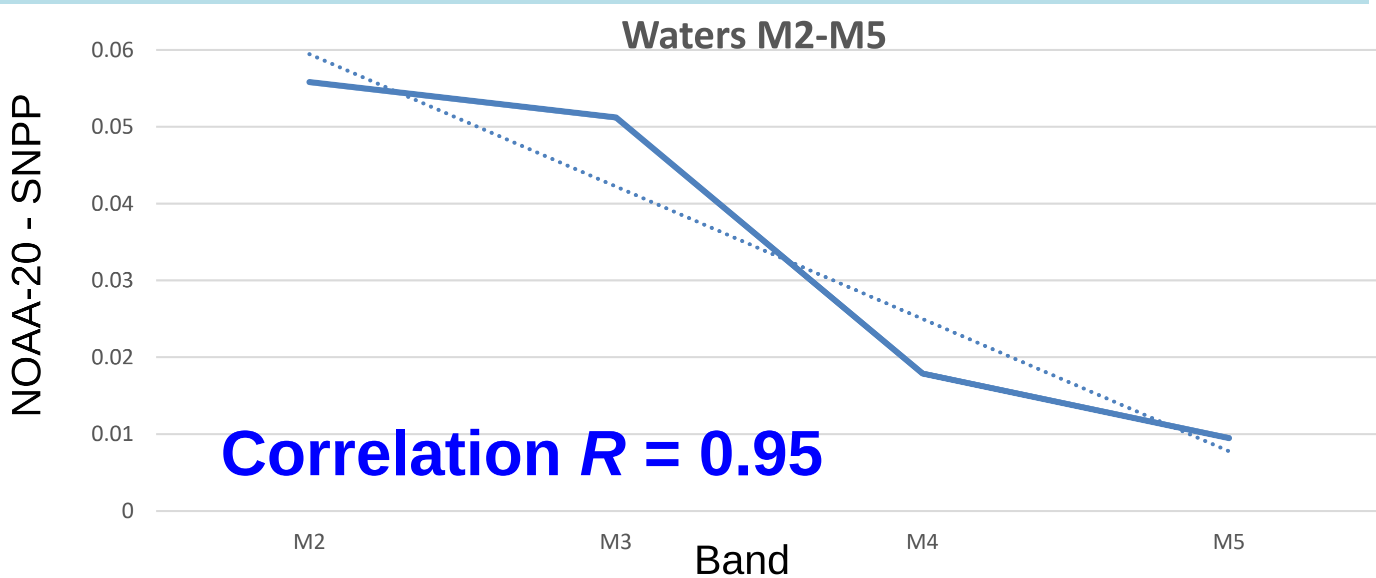
Menghua Wang, NOAA/NESDIS/STAR

nL_w Errors in the Contributing Sensor Bands Spectrally Correlated



With the strong spectral correlation in error, one only needs to show that the nL_w at the blue 445 nm meets the requirements.

Results show strong spectral correlation in nL_w errors
Meet the requirement!



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

Documentations (Check List, 1 slide)

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes (SNPP or will be)
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes (SNPP)
(External/Internal) Users Manual	Yes (SNPP)
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 - 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 VIIRS-SNPP global ocean color data, showing good quality data after April 27, 2018.
Product analysis is sufficient to communicate product performance to users relative to expectations (Performance Baseline).	Yes---Quantitative statistics results 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 to resolve SDR calibration issues. VIIRS-NOAA-20 will produce the same data quality as VIIRS-SNPP.
Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.	Yes---For VIIRS data derived after April 27, 2018.

Going Forward: Future Plans

- The main issue for path forwarding to the validated status is to improve (or correct) VIIRS-NOAA-20 SDR data quality, particularly for the data before April 27, 2018. There are also potential issues with sudden changes of F-Factors sometime near future due to sensor degradation.
  - The entire VIIRS-NOAA-20 SDR data required to be reprocessed and errors need to be corrected (e.g., remove those jumps in F-Factors, account for the sensor degradation with time).
  - As demonstrated in VIIRS-SNPP, the Ocean Color Team will look into possibility to generate high quality VIIRS-NOAA-20 SDR for improved VIIRS-NOAA-20 ocean color products.
  - Therefore, same as in VIIRS-SNPP, VIIRS-NOAA-20 science quality ocean color data will be routinely generated in a delayed mode.
- MOBY in situ data: The MOBY team will generate more MOBY in situ data, including MOBY data post-processing to improve MOBY in situ data quality. Therefore, MOBY in situ data will be used for VIIRS-NOAA-20 sensor on-orbit vicarious calibration (as did for VIIRS-SNPP).
- The Cal/Val team will finish the 2018 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 conduct the 2019 VIIRS dedicated cruise in the spring 2019. These dedicated cruise in situ data will be used for VIIRS-NOAA-20 ocean color data validation.
- More in situ data are needed and will be provided from the 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 coastal/inland waters. In particular, significant efforts are needed for coastal/inland waters.
- Continue working on VIIRS ocean color data applications for users (connecting users for VIIRS OC data).

Conclusion

- VIIRS-NOAA-20 ocean color products have been routinely produced since its launch in Nov. 2017. In particular, VIIRS-SNPP and VIIRS-NOAA-20 merged Chl-a and K_d(490) have been routinely produced, showing improved data coverage with no observable artifacts.
- Due to VIIRS-NOAA-20 calibration issues before April 27, 2018, we have made significant effort (and focused on) for deriving accurate global ocean color products for the time period after April 27, 2018.
- We have extensively evaluated VIIRS-NOAA-20 ocean color data using MOBY in situ data and global data from VIIRS-SNPP.
- Results show that, for the time period after April 27, 2018, VIIRS-NOAA-20-derived ocean color data agree very well with in situ data and global VIIRS-SNPP measurements. The ocean color data quality in that period is high and meet the data quality (accuracy and precision) requirements.
- Over open oceans and for the time period after April 27, 2018, VIIRS-NOAA-20 OC normalize water-leaving radiance spectra (M1-M5), Chl-a, and K_d(490) show excellent agreements with those from VIIRS-SNPP.
- However, for the time period before April 27, 2018, there are some important data quality problems due to SDR calibration issues. It is particularly noted that VIIRS-NOAA-20 OC EDR problems before April 27, 2018 can be resolved after fixing the SDR issues.
- Significant efforts for VIIRS on-orbit calibration is needed in order to meet ocean color requirements, as well as vicarious calibrations using **MOBY** in situ data.
- We have successfully completed 2018 NOAA dedicated Cal/Val cruise and plan to have it in the spring of 2019, providing important in situ data for VIIRS-NOAA-20 OC validation. Significant efforts for in situ data collection and data analysis are needed.
- Significant effort for improve various algorithms in MSL12, in particular, over coastal/inland waters is required.
- **Based on the definition and the evidence shown in the presentation, VIIRS-NOAA-20 ocean color EDR (for the time period after April 27, 2018) has met the Provisional stage, and is ready for operational evaluation.** It should be noted that further improvement in both SDR and EDR are needed, particularly for coastal/inland waters. In addition, very positive responses from various users for VIIRS-SNPP OC data, and VIIRS-NOAA-20 produced comparable OC data quality.