NOAA Ocean Color Cal/Val Efforts and Activities

Menghua Wang &
NOAA/STAR Ocean Color Team

The Ocean Color Team, NOAA/NESDIS/STAR
E/RA3, Room 3228, 5830 University Research Ct.
College Park, MD 20740, USA

NASA/GEO AquaWatch Validation Workshop, June 7-9, 2022

Website for VIIRS ocean color images, data and Cal/Val:
http://www.star.nesdis.noaa.gov/sod/mecb/color/

Ocean Color Data Distributions:
https://coastwatch.noaa.gov/

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

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, K. Mikelsons, 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
Ocean Color	**Sherwin Ladner**, Robert Arnone	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
	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	LISC (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

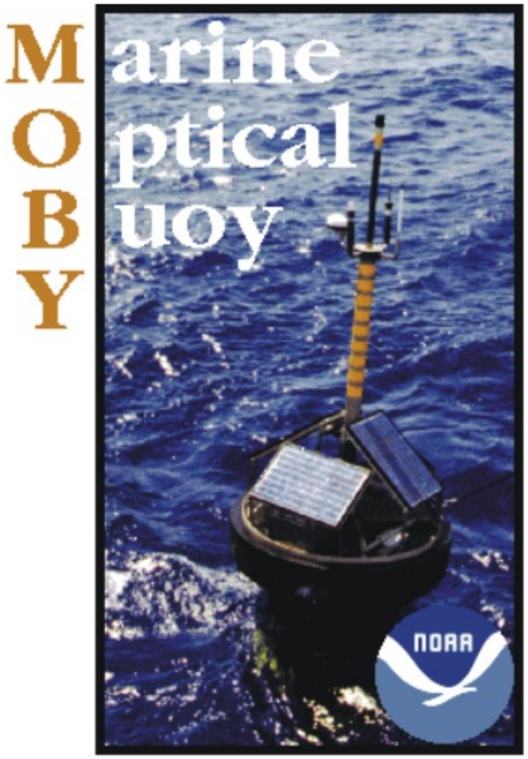
Working with: **NOAA CoastWatch**, VIIRS SDR team, DPA/DPE, Raytheon, NOAA OC Working Group, Columbia Univ. Group, NOAA various line-office reps, NOAA NCEI, NOAA OCPOP, IOCCG, NASA, ESA, EUMETSAT, JAXA, etc.

Collaborators: D. Antoine (BOUSSOLE), B. Holben (NASA-GSFC), G. Zibordi (JRC-Italy), R. Frouin (for PAR), and many others.

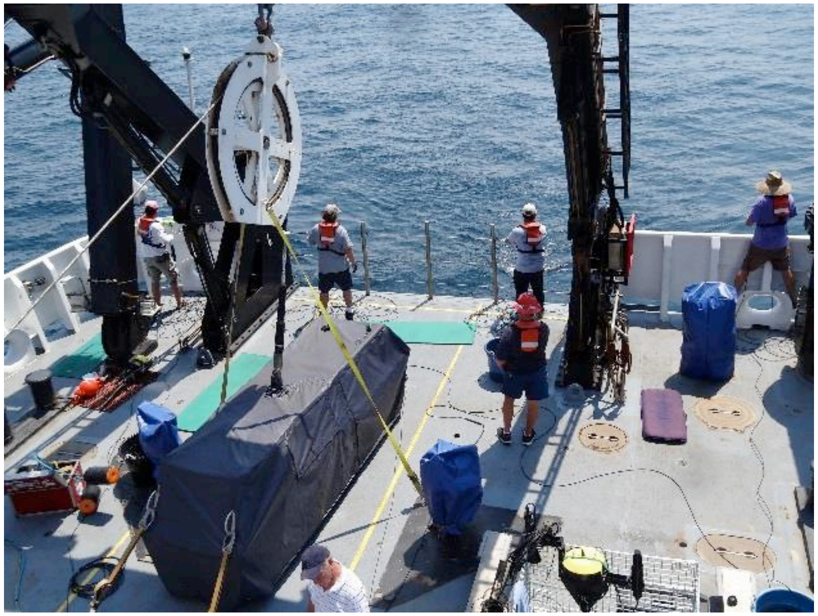
End-to-End Ocean Color Data Processing

- NOAA Ocean Color Team has been developing/building the capability for the **End-to-End** satellite ocean color data processing including:
  - Level-0 (or Raw Data Records (RDR)) to Level-1B (or Sensor Data Records (SDR)).
  - Level-1B (SDR) to ocean color Level-2 (Environmental Data Records (EDR) using the Multi-Sensor Level-1 to Level-2 (MSL12) ocean color data processing.
  - Level-2 to global Level-3 (routine daily, 8-day, monthly, and climatology data/images).
  - Validation of satellite ocean color products (in situ data and data analysis capability).
- Support of in situ data collections for VIIRS Cal/Val activities, e.g., **MOBY**, **AERONET-OC** sites (3 sites operation, added Lake Erie site), **NOAA dedicated Cal/Val cruises** (2014, 2015, 2016, 2018, 2019, 2021, 2022, ….,)
- **On-orbit vicarious calibration using MOBY in situ data:**
  - M. Wang, W. Shi, L. Jiang, and K. Voss, "NIR- and SWIR-based on-orbit vicarious calibrations for satellite ocean color sensors," *Opt. Express*, **24**, 20437-20453, 2016.
- **On-orbit instrument calibration (solar and lunar) for ocean color data processing:**
  - J. Sun and M. Wang, "Radiometric calibration of the VIIRS reflective solar bands with robust characterizations and hybrid calibration coefficients," *Appl. Opt.*, **54**, 9331–9342, 2015.
- **RDR (Level-0) to SDR (Level-1B) data processing** (efficient RDR to SDR processing)**:**
  - Sun, J., M. Wang, L. Tan, and L. Jiang, "An efficient approach for VIIRS RDR to SDR data processing," *IEEE Geosci. Remote Sens. Lett.*, **11**, 2037–2041, 2014.
- **Ocean Color Viewer (OCView)**—Online display and monitoring of ocean color product imagery.
- **Routine ocean color data quality monitoring/validation using in situ measurements**
  - MOBY in situ data for monitoring sensor performance.
  - AERONET-OC in situ data for ocean color data quality over coastal and inland waters
  - Other in situ data
- **Work with users to meet their requirements**)—e.g., Global gap-free ocean color product data.

In Situ Validation Activities



- MOBY (**D. Clark**, K. Voss)
- Dedicated VIIRS Cal/Val cruises — Annual on NOAA ships; supported by JPSS and NOAA Office of Marine and Aviation Operations
- Cruises of opportunity — in collaboration with other NOAA programs and outside
- AERONET-OC support (operation for 3 sites, Lake Erie site, etc.)
- Other in situ data sets, e.g., SeaBASS, other data sets



International Collaboration

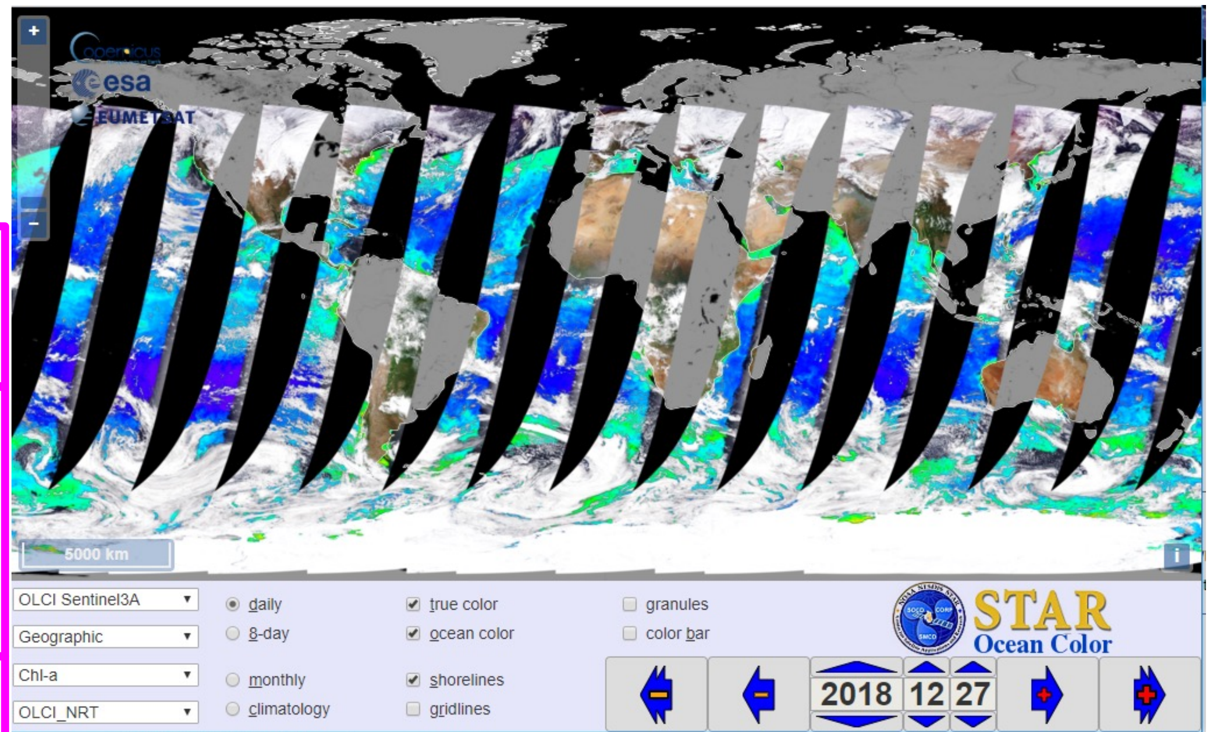
Leveraging international data and services for mutual benefits:

NOAA is primary US distributor for Copernicus Marine Data from Sentinels

NOAA OCView
- Hosts OLCI (EUMETSAT) and SGLI (JAXA) ocean color & true color imageries

NOAA CoastWatch
- Produces routine L3 for Mediterranean for EUMETSAT operational use
- Hosts several satellite ocean color and true color imageries/data

Co-hosting with EUMETSAT the 1st and 2nd International Operational Satellite Oceanography Symposiums

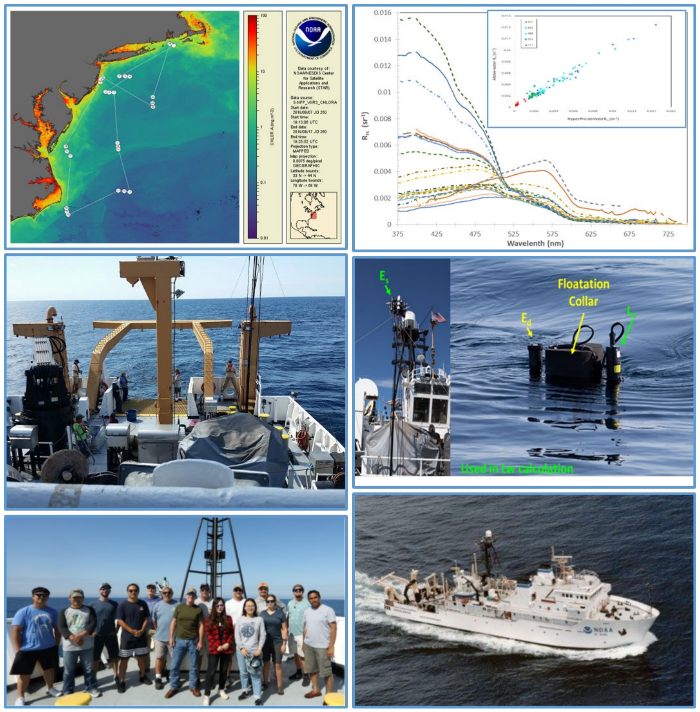


Including:

VIIRS SNPP, NOAA-20, OLCI Sentinel-3A, Sentinel-3B, SGLI-GCOM-C, and GOCI

NOAA Technical Report NESDIS 154
DOI: 10.25923/p9de-yw97

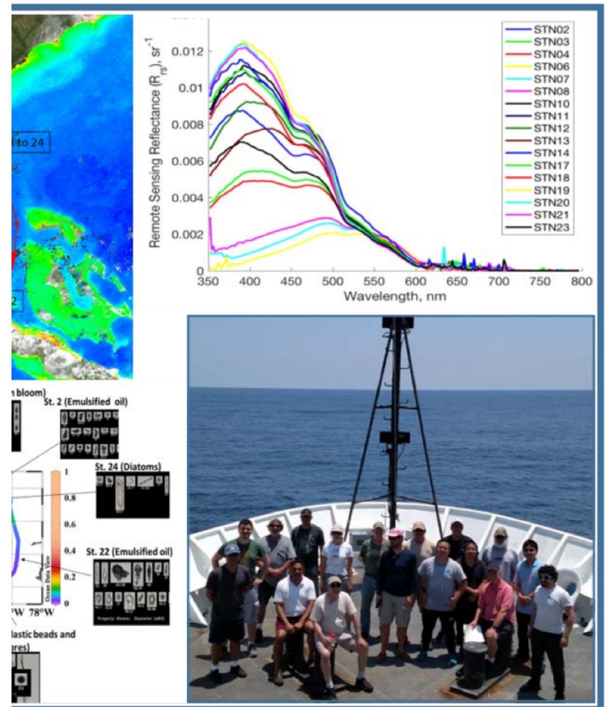
Report for
Dedicated JPSS VIIRS Ocean Color Calibration/Validation Cruise
September 2019



Washington, D.C.

Report NESDIS 152

IIRS Ocean Color
ation Cruise



The 7th OC Cal/Val cruise was successfully completed in March 2022!

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

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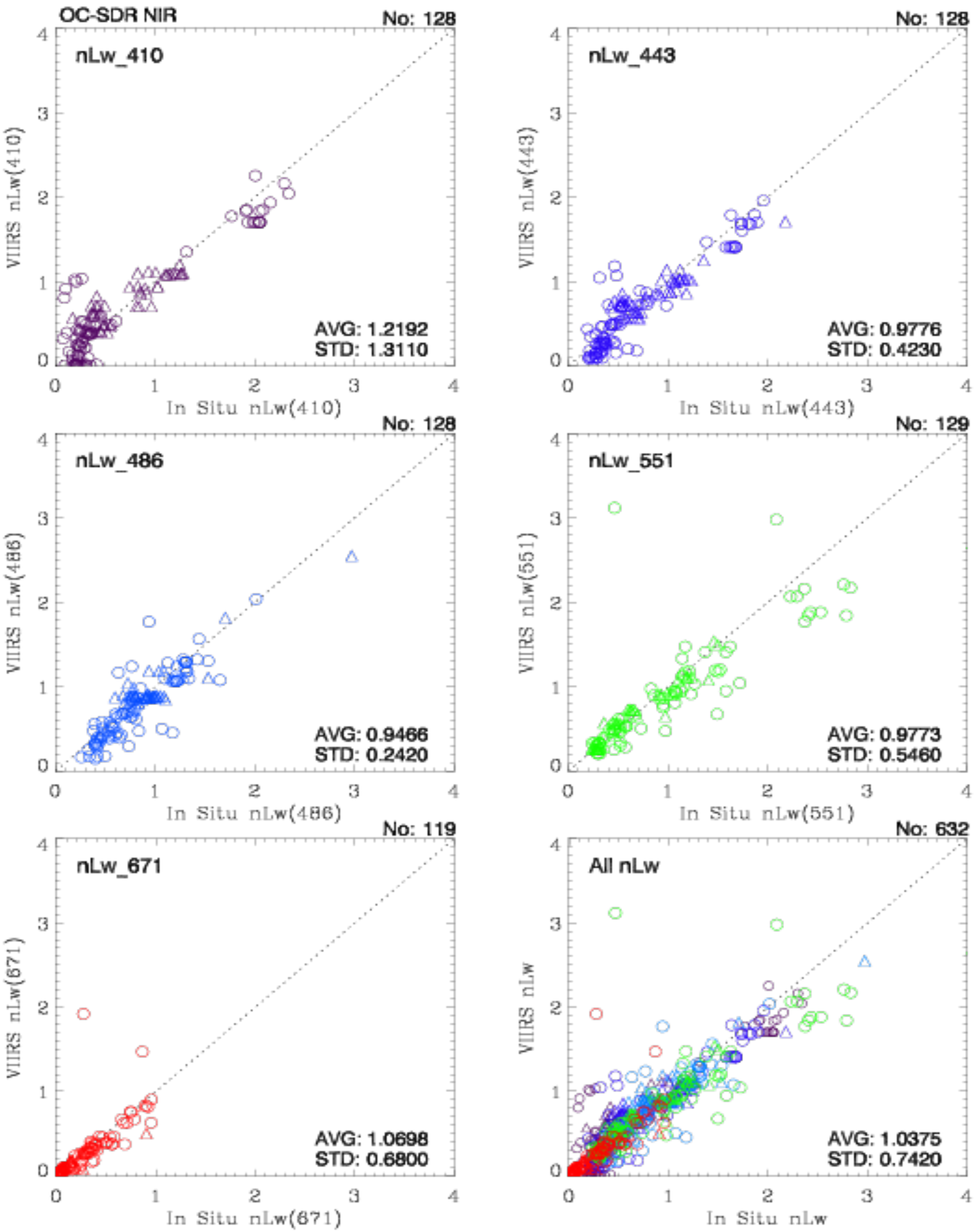
nic and Atmospheric Administration

The 8th OC Cal/Val cruise will be over the west coast of California in 2023!

Published Cal/Val Cruise Reports

- Ondrusek, M., V. P. Lance, M. Wang, E. Stengel, C. Kovach, S. Freeman, A. Mannino, A. Gilerson, C. Carrizo, P. Grotsch, E. Herrera, M. Malinowski, S. Ahmed, J. I. Goes, J. Wu, H. Gomes, K. McKee, C. Hu, J. Cannizzaro, Y. Zhang, Y. Zhang, D. English, S. Ladner, W. Goode, Z. P. Lee, J. Wei, Z. Shang, M. Twardowski, N. Stockley, C. Strait, and K. J. Voss, "Report for Dedicated JPSS VIIRS Ocean Color Calibration/Validation Cruise September 2019," NOAA Technical Report NESDIS 154, V. P. Lance (ed.), NOAA National Environmental Satellite, Data, and Information Service, Silver Spring, Maryland, 2021. https://doi.org/10.25923/p9de-yw97
- Ondrusek, M., V. P. Lance, M. Wang, E. Stengel, C. Kovach, R. Arnone, S. Ladner, W. Goode, A. Gilerson, A. El-Habashi, C. Carrizo, E. Herrera, S. Ahmed, J. I. Goes, H. Gomes, K. McKee, C. Hu, J. Cannizzaro, Y. Zhang, C. Huang, D. English, B. C. Johnson, Z. P. Lee, X. Yu, Z. Shang, N. Tufillaro, I. Lalovic, and K. J. Voss, "Report for Dedicated JPSS VIIRS Ocean Color Calibration/Validation Cruise May 2018," NOAA Technical Report NESDIS 152, V. P. Lance (ed.), NOAA National Environmental Satellite, Data, and Information Service, Silver Spring, Maryland, 2019. https://doi.org/10.25923/scyb-qf42
- Ondrusek, M., V. P. Lance, M. Wang, E. Stengel, C. Kovach, R. Arnone, S. Ladner, W. Goode, A. Gilerson, S. Ahmed, A. El-Habashi, R. Foster, M. Ottaviani, J. I. Goes, H. Gomes, K. McKee, J. W. Kang, C. Hu, J. Cannizzaro, S. Sun, D. English, B. C. Johnson, Z. P. Lee, L. Zoffoli, J. Lin, N. Tufillaro, I. Lalovic, J. Nahorniak, C. O. Davis, M. Twardowski, N. Stockley, and K. J. Voss, "Report for Dedicated JPSS VIIRS Ocean Color Calibration/Validation Cruise October 2016," NOAA Technical Report NESDIS 151, V. P. Lance (ed.), NOAA National Environmental Satellite, Data, and Information Service, Silver Spring, Maryland, 2017. https://doi.org/10.7289/V5/TR-NESDIS-151
- Ondrusek, M., V. P. Lance, E. Stengel, M. Wang, R. Arnone, S. Ladner, W. Goode, R. Vandermeulen, S. Freeman, J. E. Chaves, A. Mannino, A. Gilerson, S. Ahmed, C. Carrizo, A. El-Habashi, R. Foster, M. Ottaviani, J. I. Goes, H. Gomes, K. McKee, C. Hu, C. Kovach, D. English, J. Cannizzaro, B. C. Johnson, Z. P. Lee, J. Wei, Q. Wang, J. Lin, N. Tufillaro, J. Nahorniak, C. O. Davis, and K. J. Voss, "Report for Dedicated JPSS VIIRS Ocean Color Calibration/Validation Cruise December 2015," NOAA Technical Report NESDIS 148, V. P. Lance (ed.), NOAA National Environmental Satellite, Data, and Information Service, Silver Spring, Maryland, 2016. https://doi.org/10.7289/V5/TR-NESDIS-148
- Ondrusek, M., E. Stengel, V. P. Lance, M. Wang, K. J. Voss, G. Zibordi, M. Talone, Z. P. Lee, J. Wei, J. Lin, C. Hu, D. English, C. Kovach, J. Cannizzaro, A. Gilerson, S. Ahmed, A. Ibrahim, A. El-Habashi, R. Foster, R. Arnone, R. Vandermeulen, S. Ladner, W. Goode, J. I. Goes, H. Gomes, A. Chekalyuk, K. McKee, S. Freeman, A. Neeley, and B. C. Johnson, "Report for Dedicated JPSS VIIRS Ocean Color Calibration/Validation Cruise," NOAA Technical Report NESDIS 146, V. P. Lance (ed.), NOAA National Environmental Satellite, Data, and Information Service, Silver Spring, Maryland, 2015. https://doi.org/10.7289/V52B8W0Z



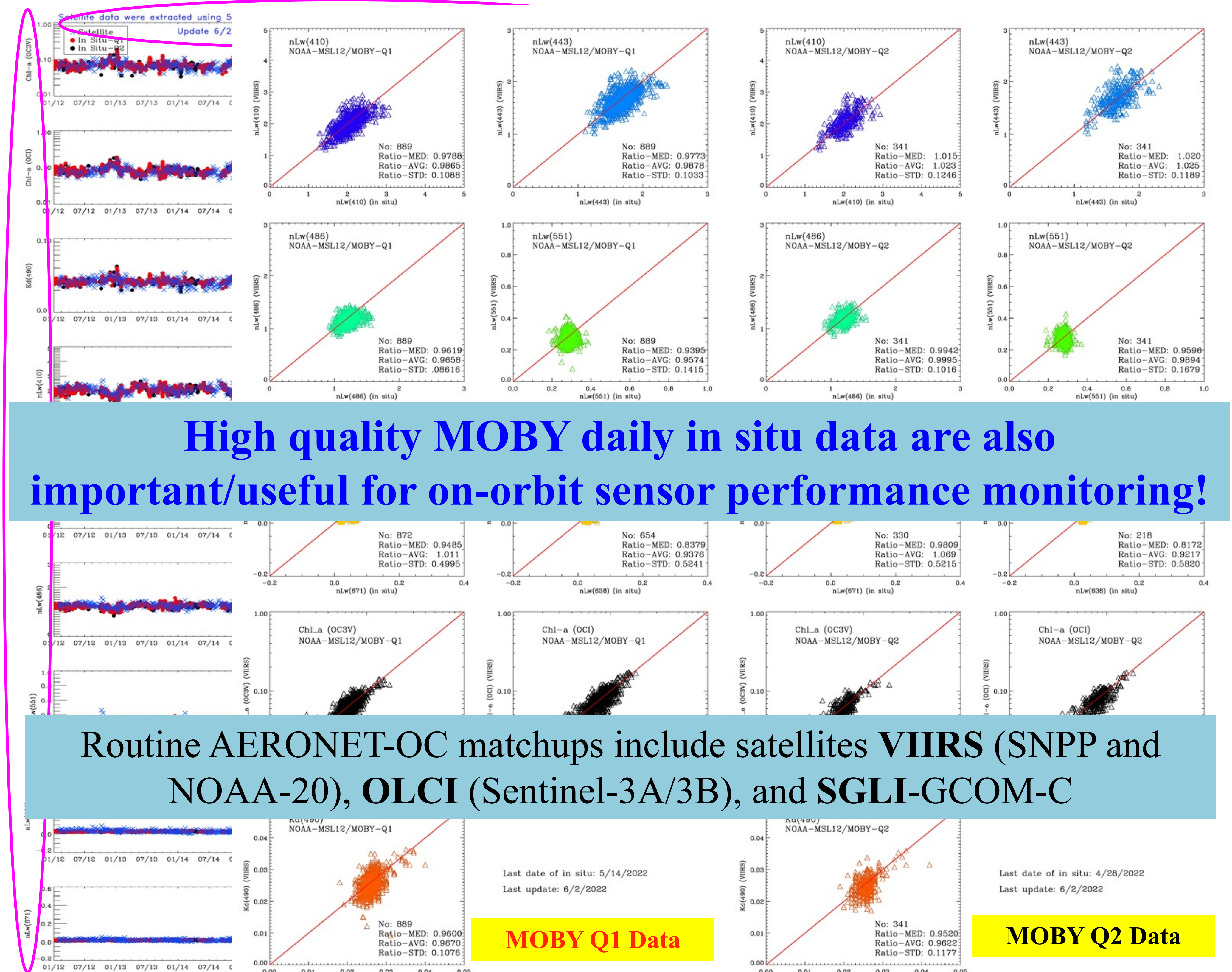
Validation Effort

VIIRS-SNPP vs. In Situ Data

<u>In Situ Data Sources:</u>

R. Arnone (U. South Miss.)
C. Davis (Oregon State U.)
C. Hu (U. South Florida)
Z. Lee (U. Mass. Boston)
M. Ondrusek (NOAA/STAR)
G. Zibordi (JRC)

- Three dedicated Cal/Val cruises (2014-2016) and
- Various in situ measurement opportunities



High quality MOBY daily in situ data are also important/useful for on-orbit sensor performance monitoring!
Routine AERONET-OC matchups include satellites **VIIRS** (SNPP and NOAA-20), **OLCI** (Sentinel-3A/3B), and **SGLI**-GCOM-C
Last date of in situ: 5/14/2022
Last update: 6/2/2022
Last date of in situ: 4/28/2022
Last update: 6/2/2022
MOBY Q1 Data
MOBY Q2 Data

Statistics of VIIRS-SNPP vs. In-Situ (MOBY) (2012–2022)

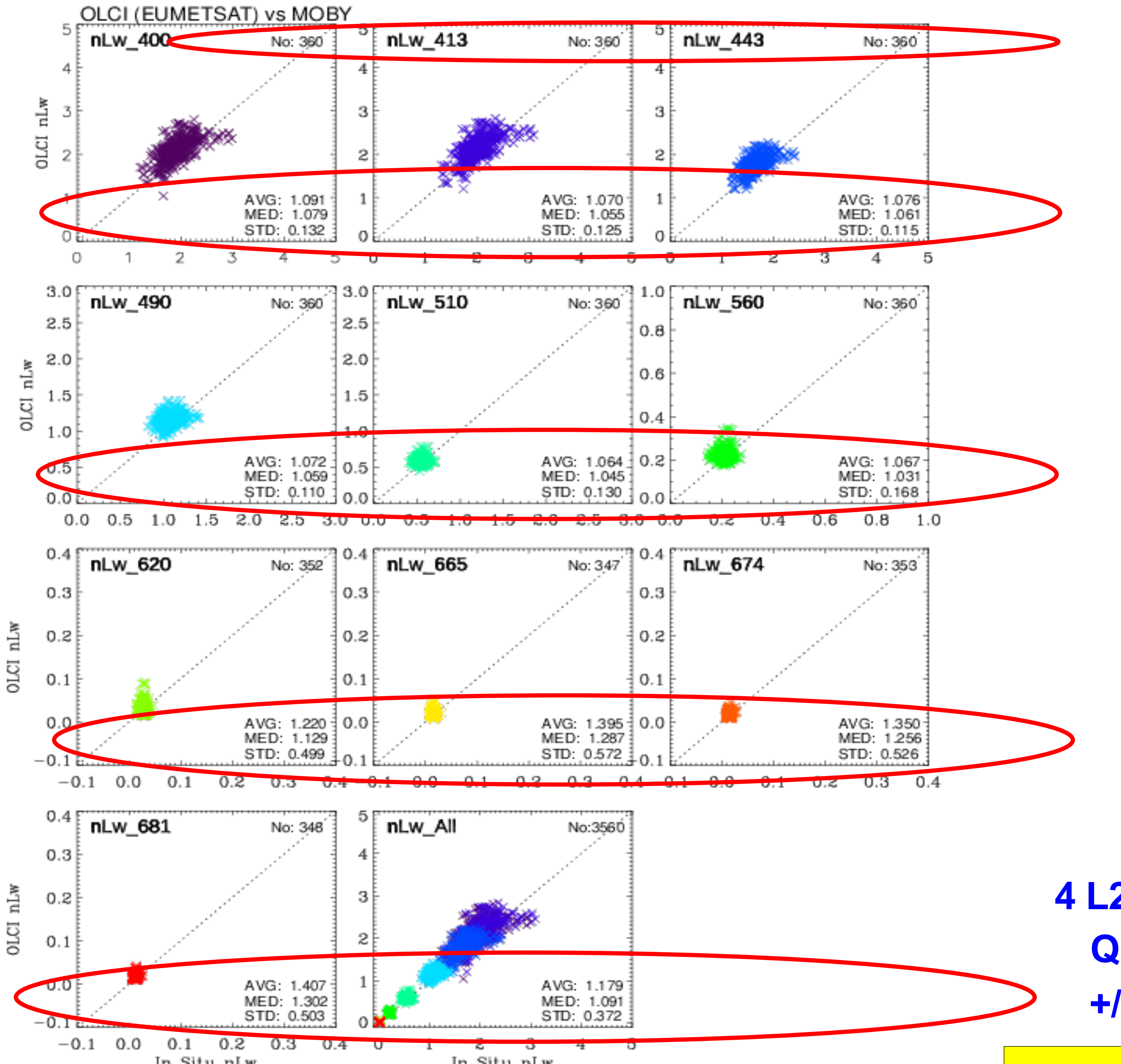
	VIIRS-SNPP vs. MOBY In Situ Data							
	RATIO (SAT/ENV)				DIFFERENCE (SAT–ENV)			
	AVG	MED	STD	No	AVG	MED	STD	%Diff
$nL_w(410)$	**1.0068**	0.9920	0.120	1236	**0.0049**	-0.0156	0.232	0.241
$nL_w(443)$	**1.0090**	0.9925	0.115	1236	**0.0078**	-0.0130	0.186	0.467
$nL_w(486)$	**0.9819**	0.9720	0.094	1236	**-0.0268**	-0.0340	0.111	-2.219
$nL_w(551)$	**0.9722**	0.9528	0.150	1236	**-0.0095**	-0.0133	0.041	-3.394
$nL_w(638)$	**0.9214**	0.8217	0.531	837	**-0.0027**	-0.0052	0.015	-9.338
$nL_w(671)$	**1.0701**	0.9831	0.488	1208	**0.0010**	-0.0004	0.009	4.614
Chl_OC3	**0.9671**	0.9670	0.187	1236	**-0.0026**	-0.0022	0.012	-3.772
Chl_OCI	**0.9795**	0.9929	0.179	1236	**-0.0025**	-0.0007	0.015	-3.025
$K_d(490)$	**0.9652**	0.9538	0.110	1236	**-0.0009**	-0.0011	0.003	-3.640

*. **MOBY Q1+Q2**

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

MOBY

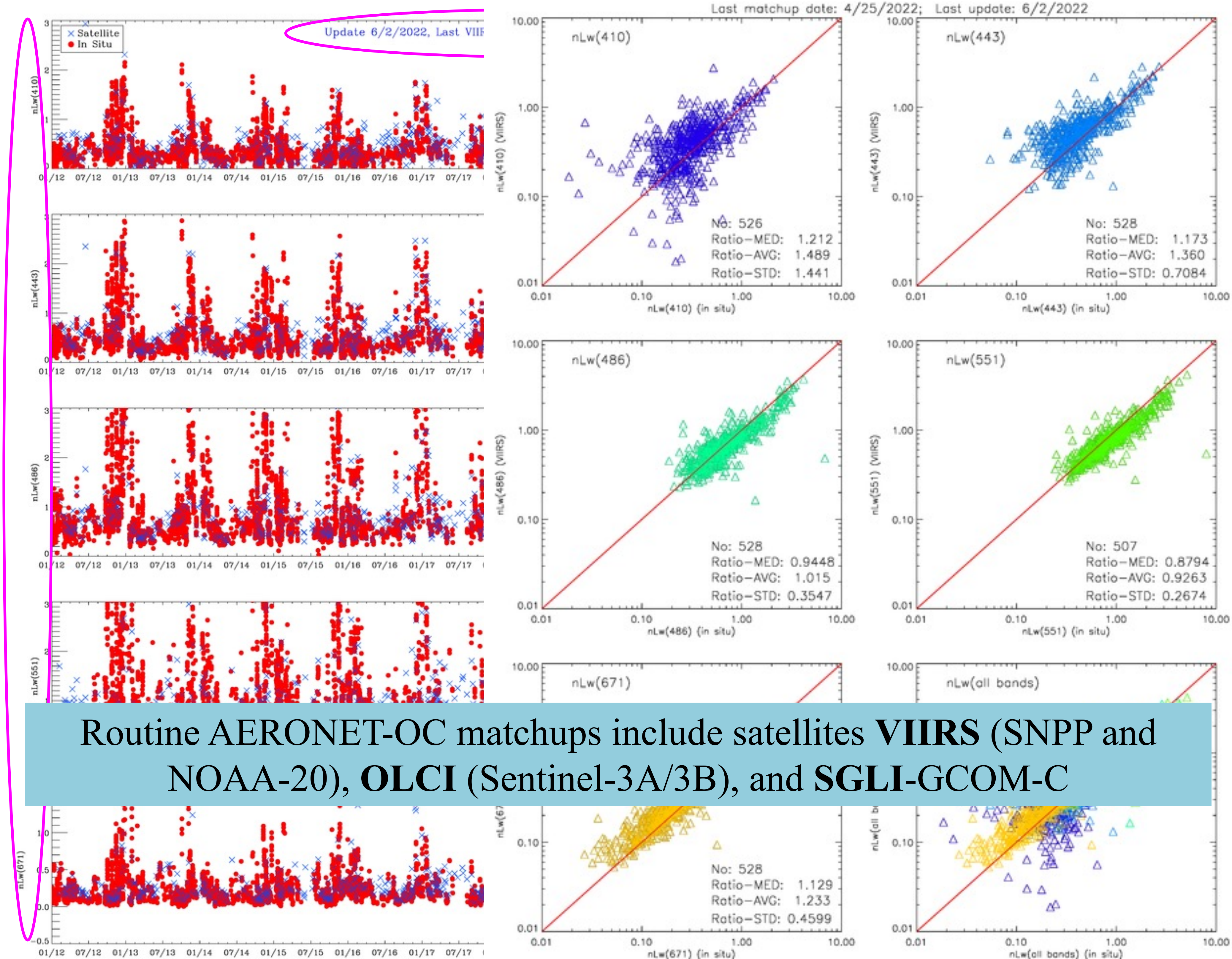
Matchup of OLCI-S3A (MSL12) & MOBY In Situ (2016 ~ 2022)



4 L2_Flags
Q1+Q2
+/-3hrs

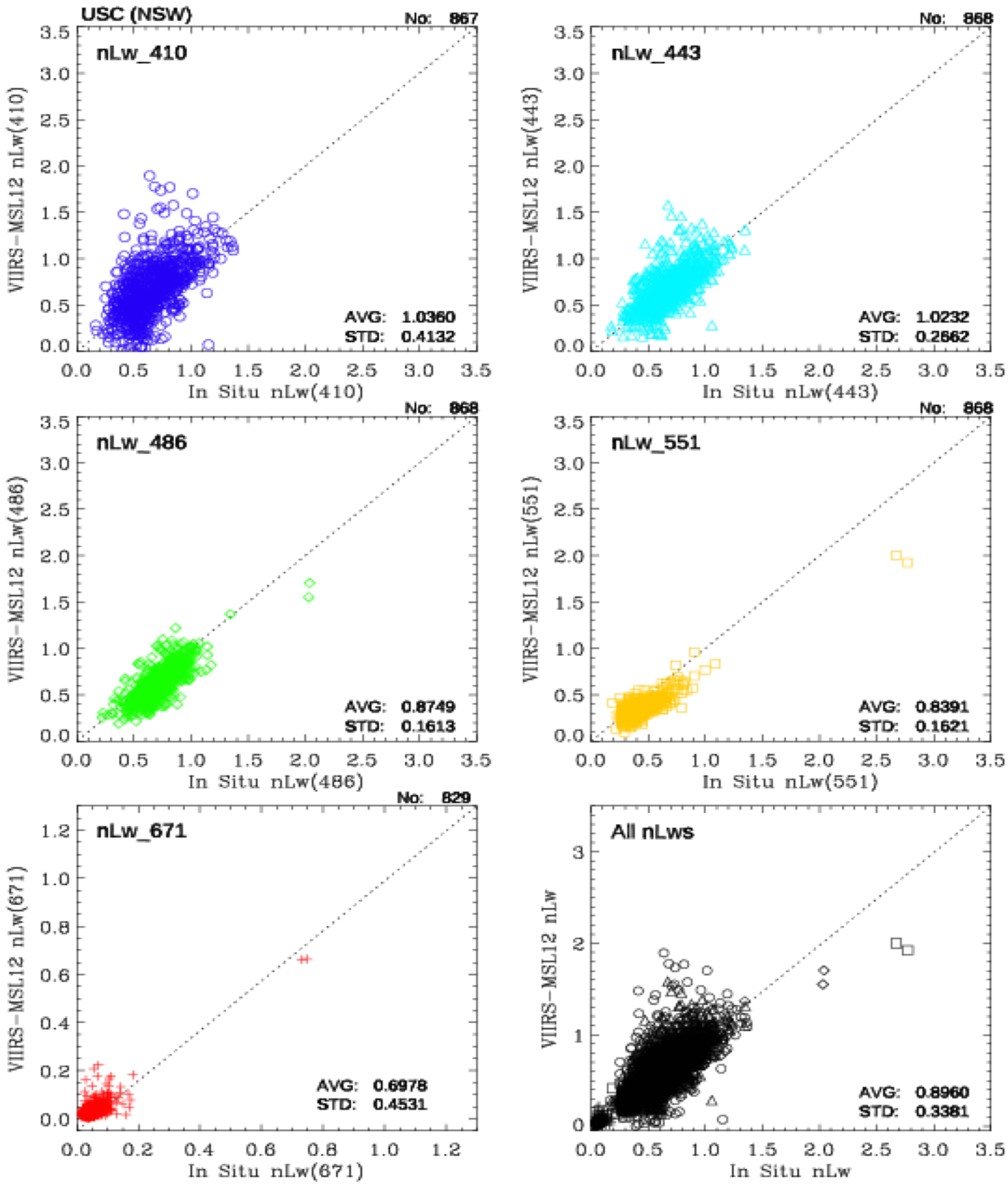
MOBY

Menghua Wang, NOAA/NESDIS/STAR



Routine AERONET-OC matchups include satellites **VIIRS** (SNPP and NOAA-20), **OLCI** (Sentinel-3A/3B), and **SGLI**-GCOM-C

VIIRS-SNPP vs. AERONET-OC (USC site)



USC

Statistics of VIIRS-SNPP vs. AERONET-OC (USC site)

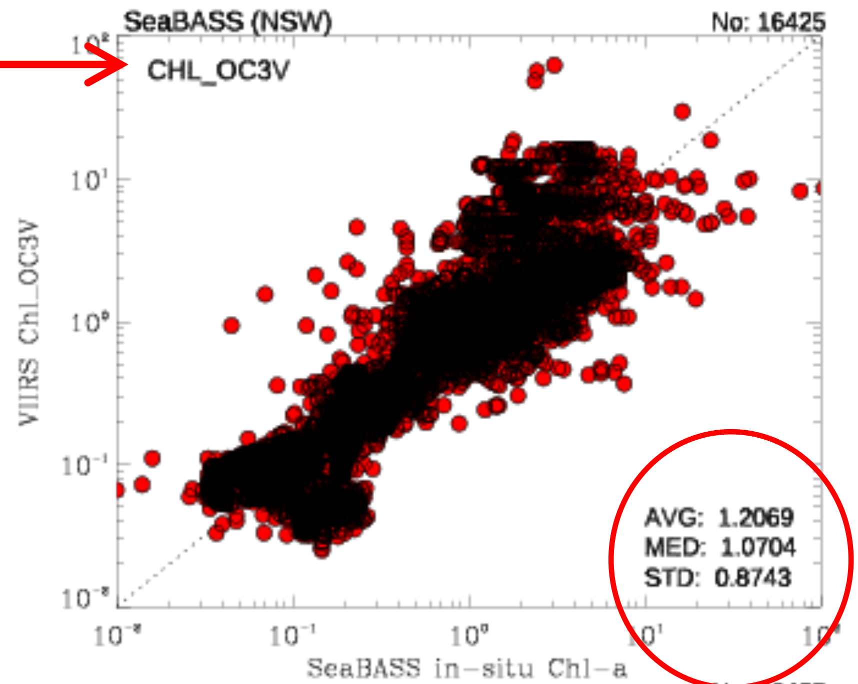
	VIIRS-SNPP vs. AERONET-OC (USC site)							
	RATIO (SAT/ENV)				DIFFERENCE (SAT−ENV)			
	AVG	MED	STD	No	AVG	MED	STD	%Diff
nL**w(412)**	**1.0360**	0.9756	0.413	867	**0.0079**	-0.0162	0.236	1.214
nL**w(443)**	**1.0232**	0.9806	0.266	868	**0.0039**	-0.0122	0.163	0.570
nL**w(488)**	**0.8749**	0.8731	0.161	868	**-0.0907**	-0.0901	0.111	-12.569
nL**w(555)**	**0.8391**	0.8237	0.162	868	**-0.0731**	-0.0712	0.078	-17.678
nL**w(672)**	**0.6978**	0.6108	0.453	829	**-0.0170**	-0.0177	0.024	-32.515
nL**w_ALL**	**0.8960**	0.8731	0.338	4300	**-0.0340**	-0.0346	0.148	-6.690

*. All Valid Pixels

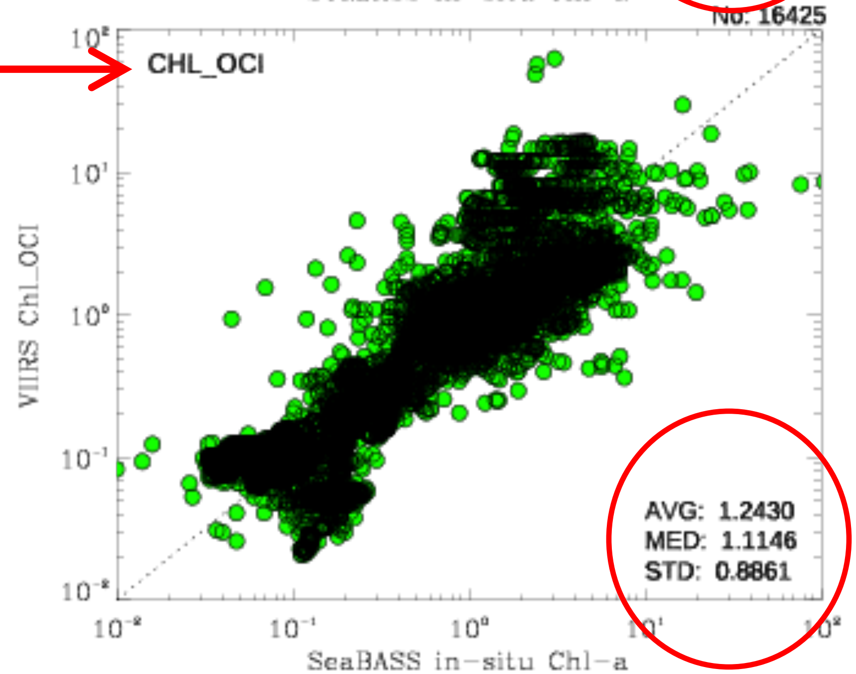
USC

Matchup of Chl-a VIIRS-SNPP versus SeaBASS In Situ (Same Day)

Empirical blue-green radiance ratio Chl-a algorithm

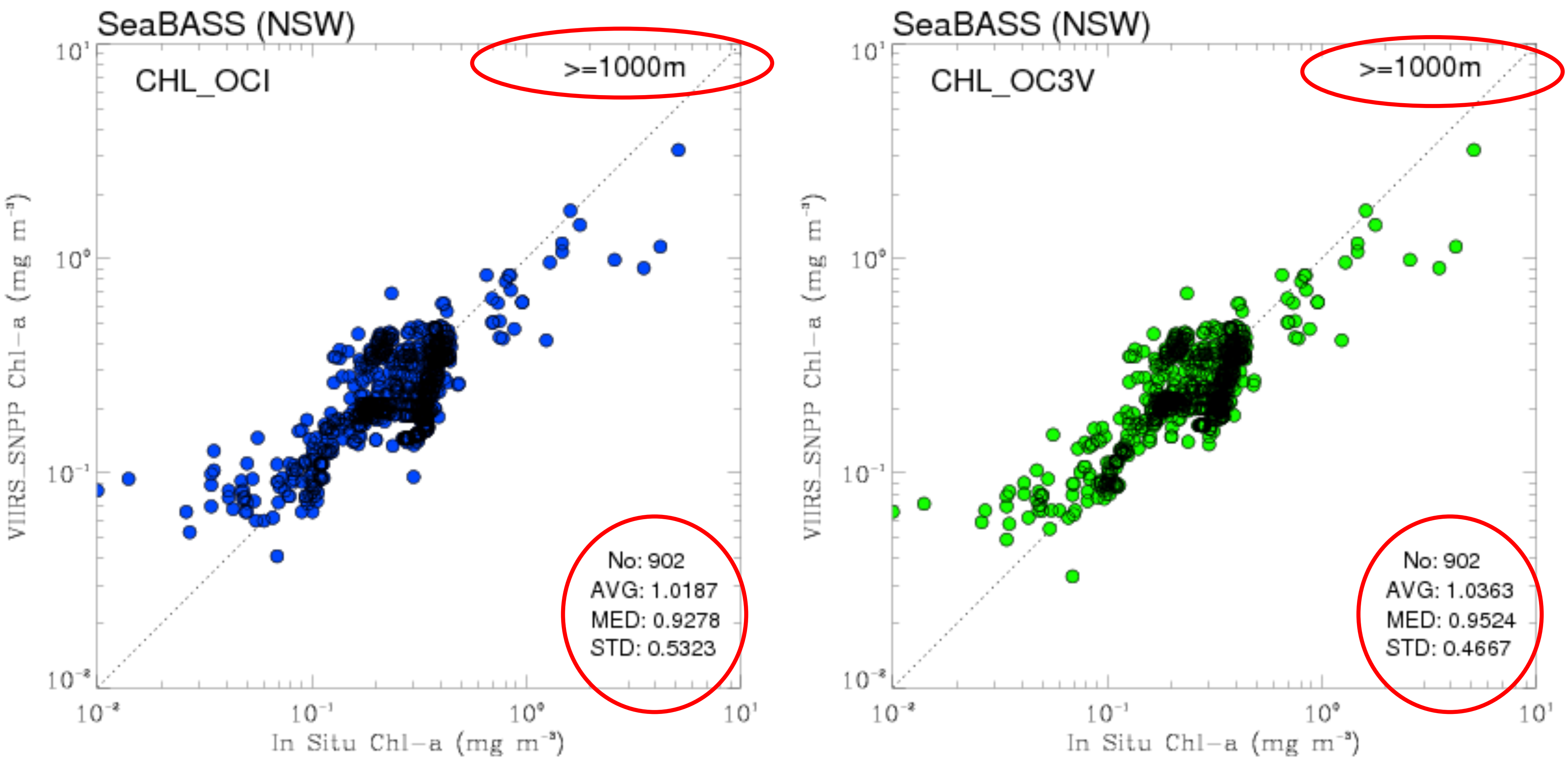


Ocean Color Index (OCI) Chl-a algorithm



SeaBASS

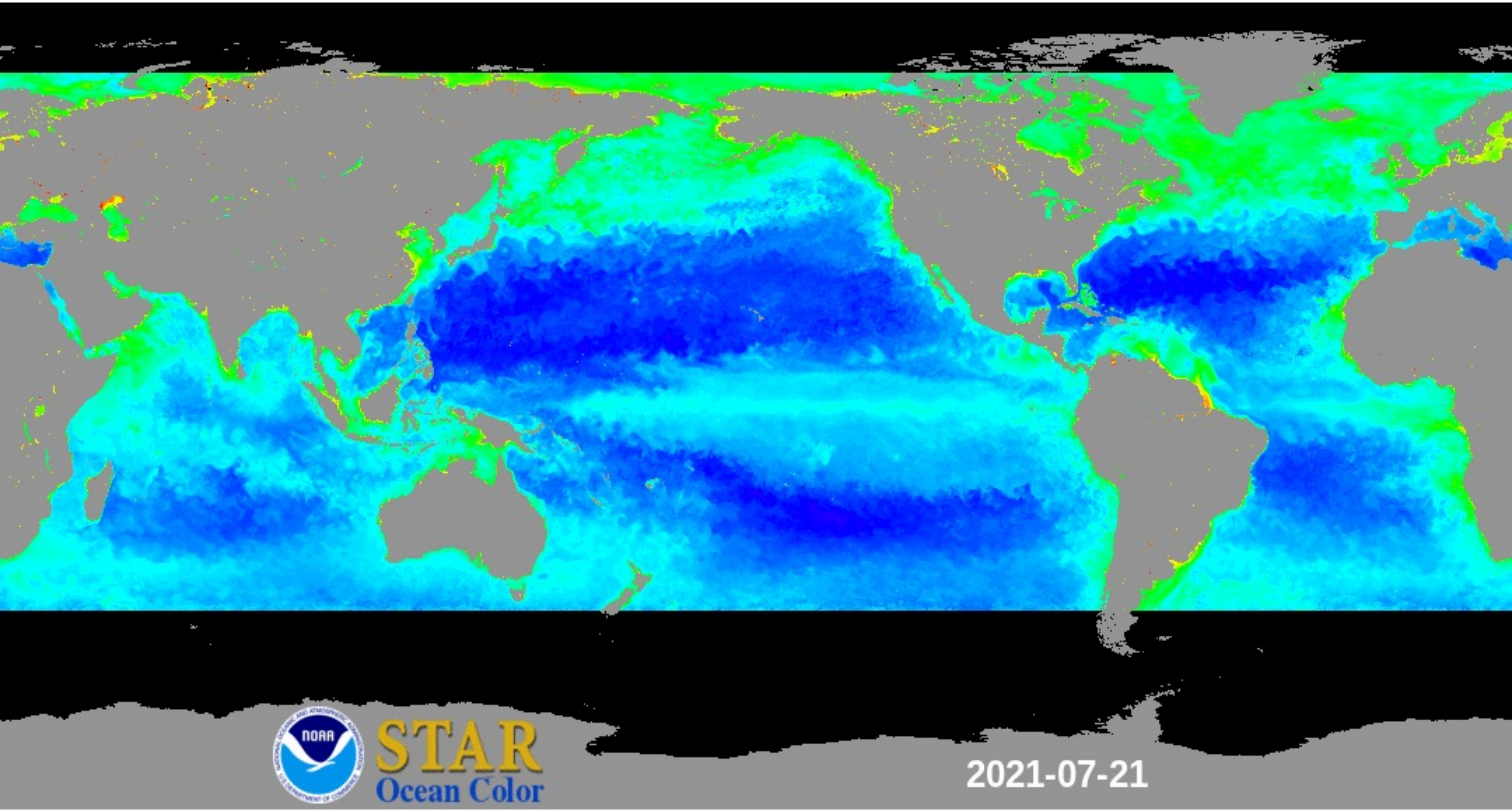
Matchup of Chl-a VIIRS-SNPP vs. SeaBASS In Situ Over Global Deep Water



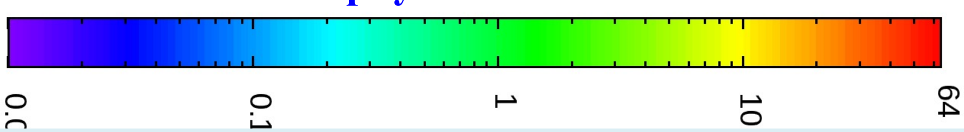
SeaBASS

Three-sensor Global Gap-Free Chl-a Data

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



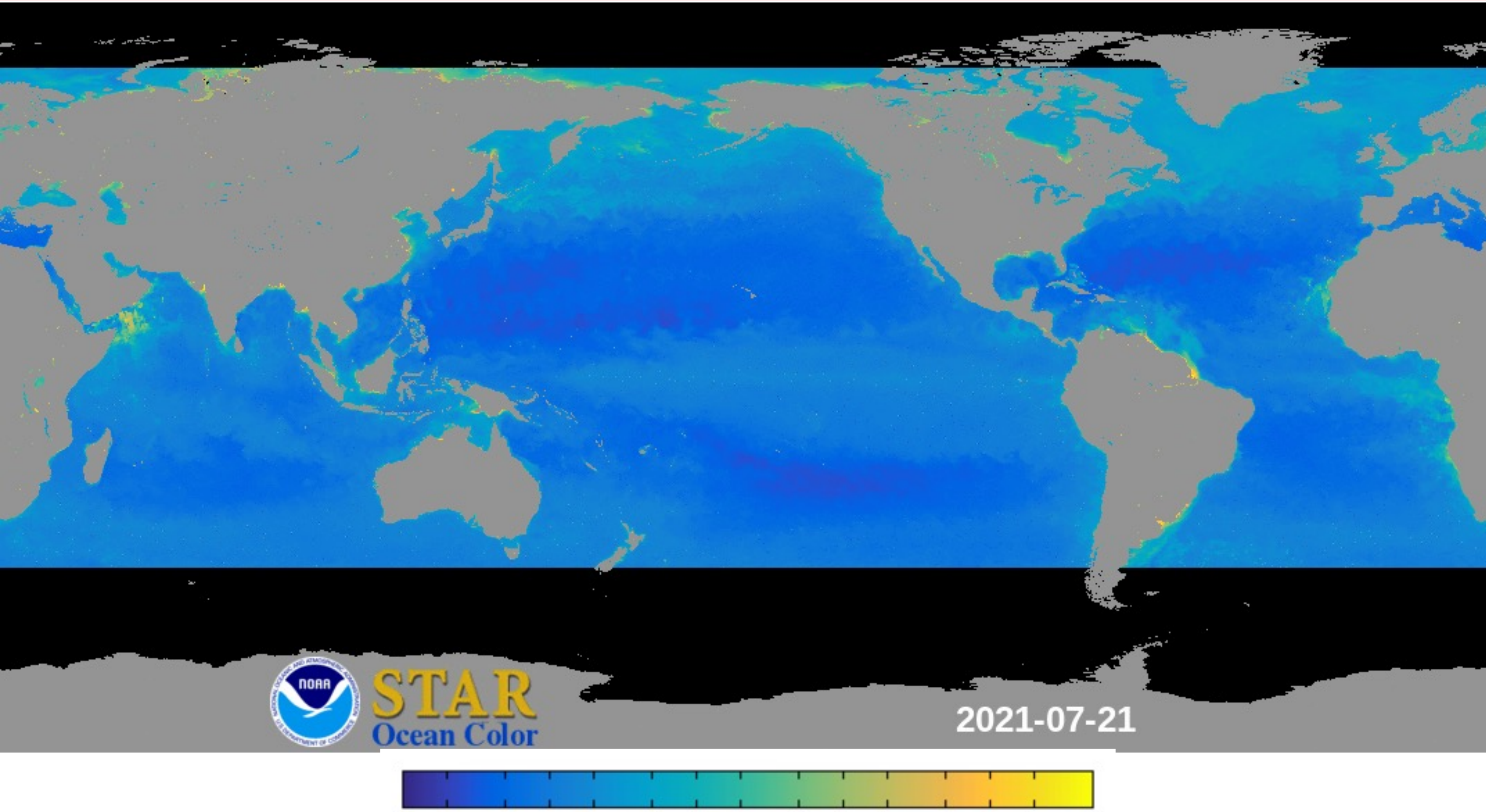
Chlorophyll-a Concentration



Wang, M. and S. Son, "VIIRS-derived chlorophyll-a using the ocean color index method," *Remote Sens. Environ.*, 182, 141–149, 2016. https://doi.org/10.1016/j.rse.2016.05.001

Three-sensor Global Gap-Free SPM Data

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



Wei, J., M. Wang, L. Jiang, X. Yu, K. Mikelsons, and F. Shen, "Global estimation of suspended particulate matter from satellite ocean color imagery," *J. Geophys. Res. Oceans*, **126**, e2021JC017303, 2021. https://doi.org/10.1029/2021JC017303

Yu, X., Z. Lee, F. Shen, M. Wang, J. Wei, L. Jiang, and Z. Shang, "An empirical algorithm to seamlessly retrieve the concentration of suspended particulate matter from water color across ocean to turbid river mouths," *Remote Sens. Environ.*, 235, 111491, 2019. https://doi.org/10.1016/j.rse.2019.111491

Conclusions

- NOAA has supported MOBY, several AERONET-OC sites, and annual dedicated Cal/Val cruises, as well as various opportunities to obtain in situ data for satellite ocean color Cal/Val effort. We will continue such efforts and activities.
- NOAA Ocean Color Team has put significant efforts to build the ocean color data quality monitoring system using in situ measurements to routinely evaluate ocean/water property data quality, as well as to monitor satellite sensor performance.
- Gap-free global daily ocean color/water quality data from multiple satellite observations have now been routinely produced, providing useful new data sets for various research and applications. Using gap-free data, efficiency of product validation can be significantly improved.

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

Ocean Color Data Distributions:
https://coastwatch.noaa.gov/

Thank You!