VIIRS Ocean Color Products and Updates

Menghua Wang &

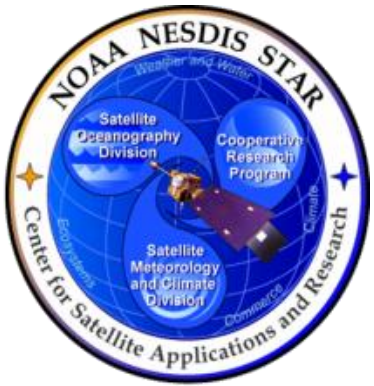
Ocean Color EDR and Cal/Val Teams

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

STAR JPSS 2017 Annual Science Team Meeting
NCWCP, College Park, Maryland, August 27-29, 2018

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

Acknowledgements: This work has been supported by JPSS/VIIRS funding. We thank MOBY team for in situ optics data, 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, 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.

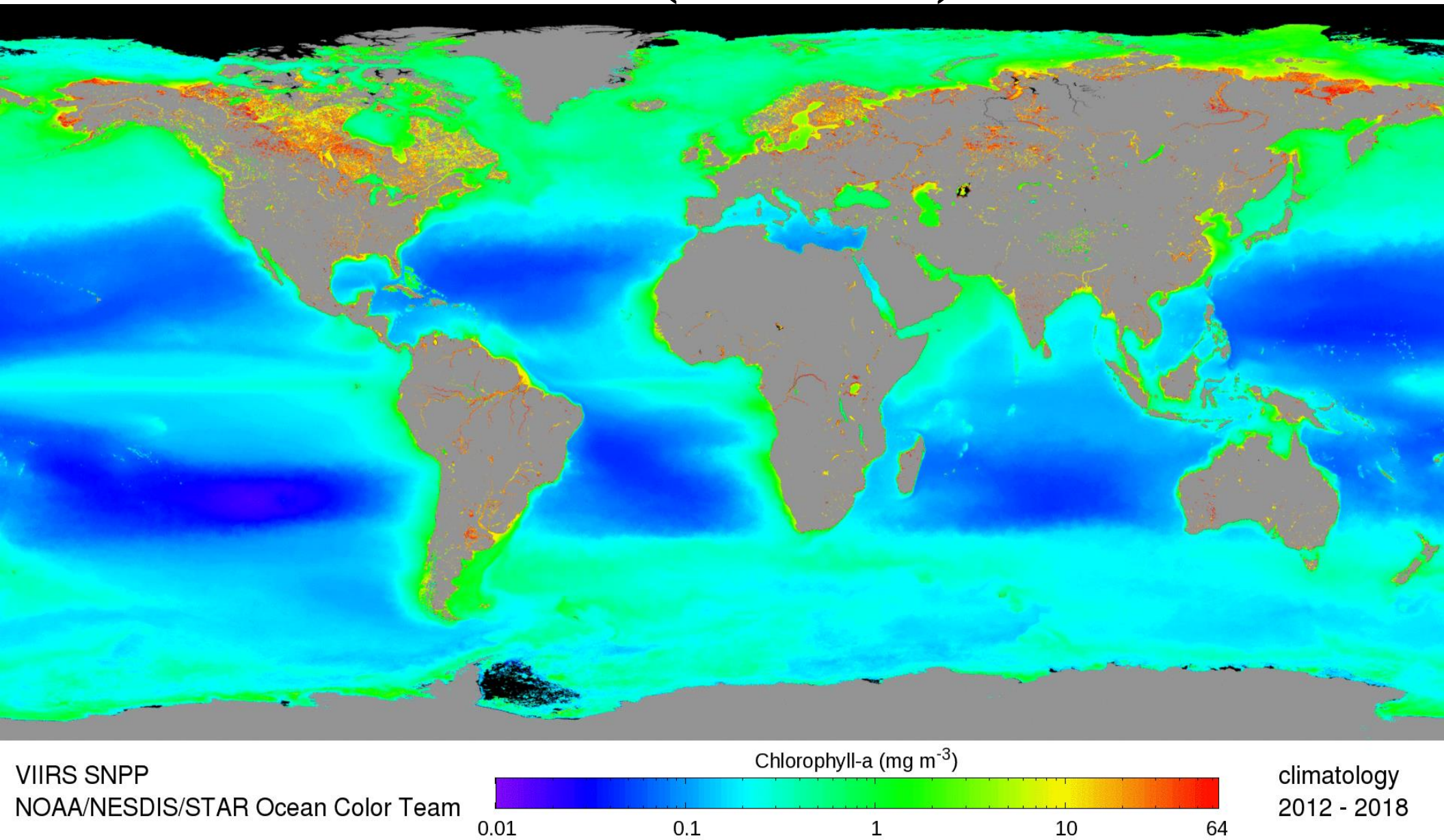
Summary of VIIRS Ocean Color EDR Products (Updates)

- **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)
  - 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…)!

VIIRS Climatology Ocean Color Product Image

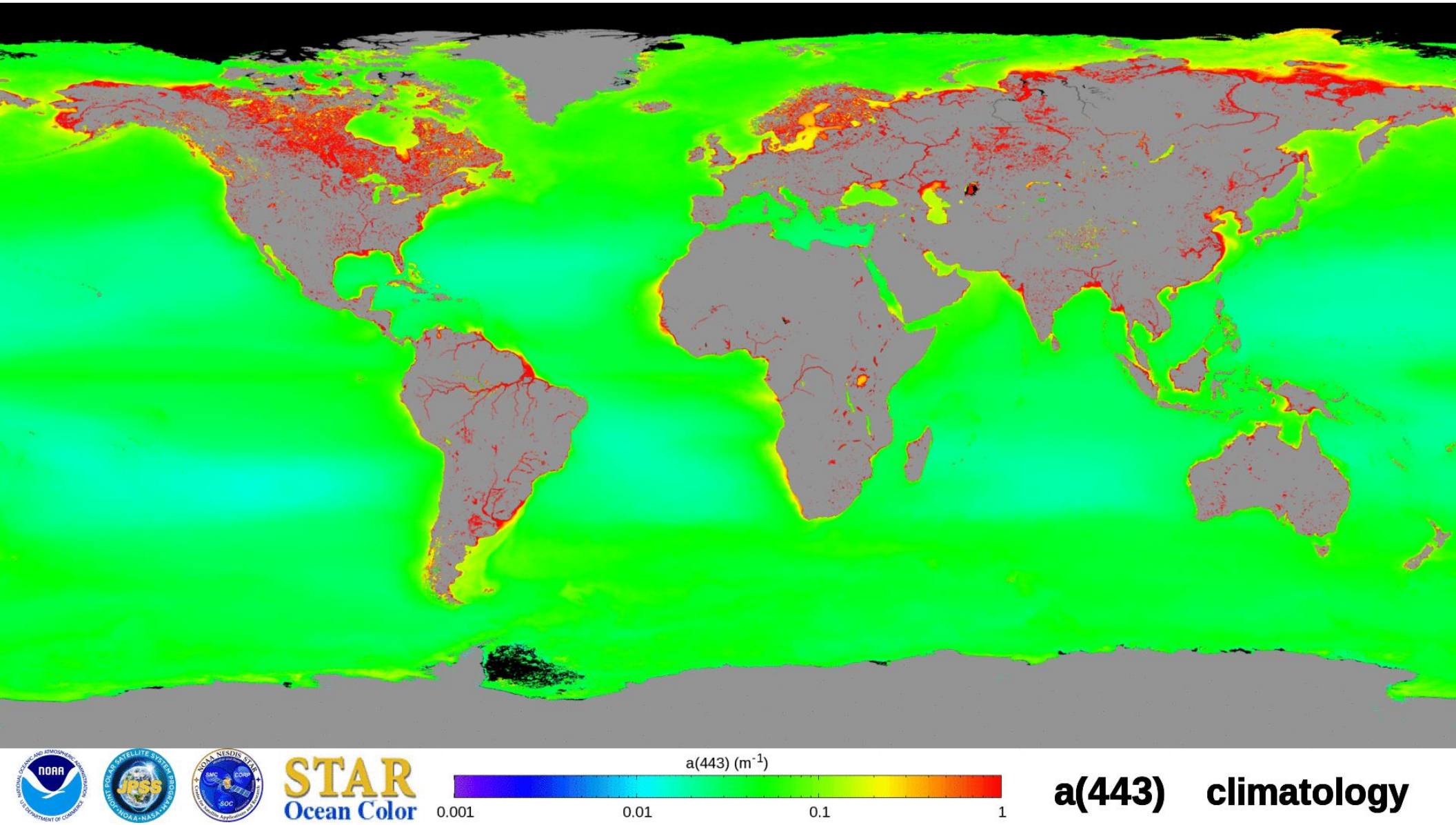
SNPP (2012–2018)



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

Menghua Wang, NOAA/NESDIS/STAR

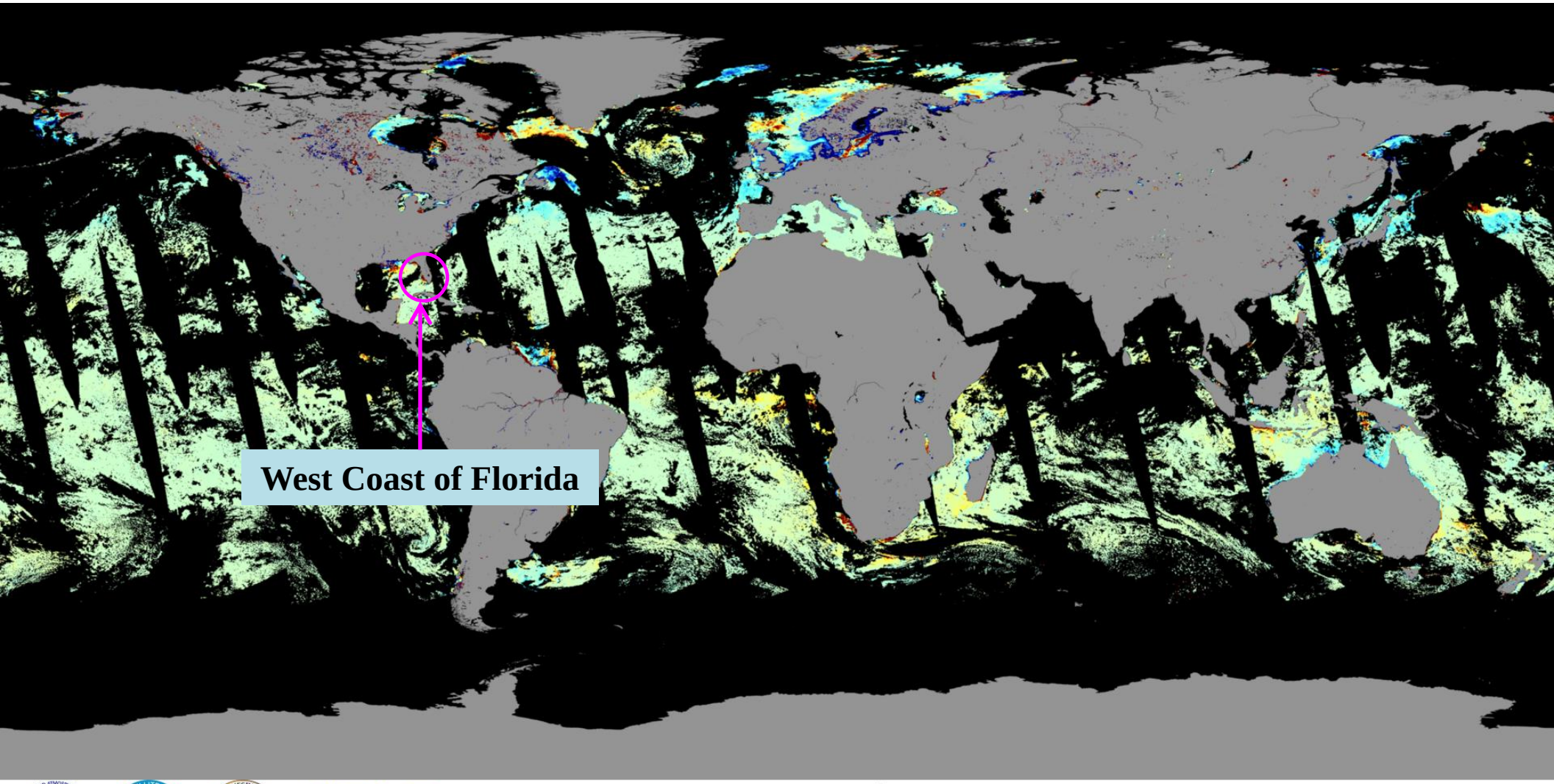
Experimental Ocean Color Product Image (Selected)
SNPP (2012–2018)



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

Menghua Wang, NOAA/NESDIS/STAR

VIIRS-SNPP Chl-a Anomaly
(July 26, 2018)



STAR Ocean Color

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

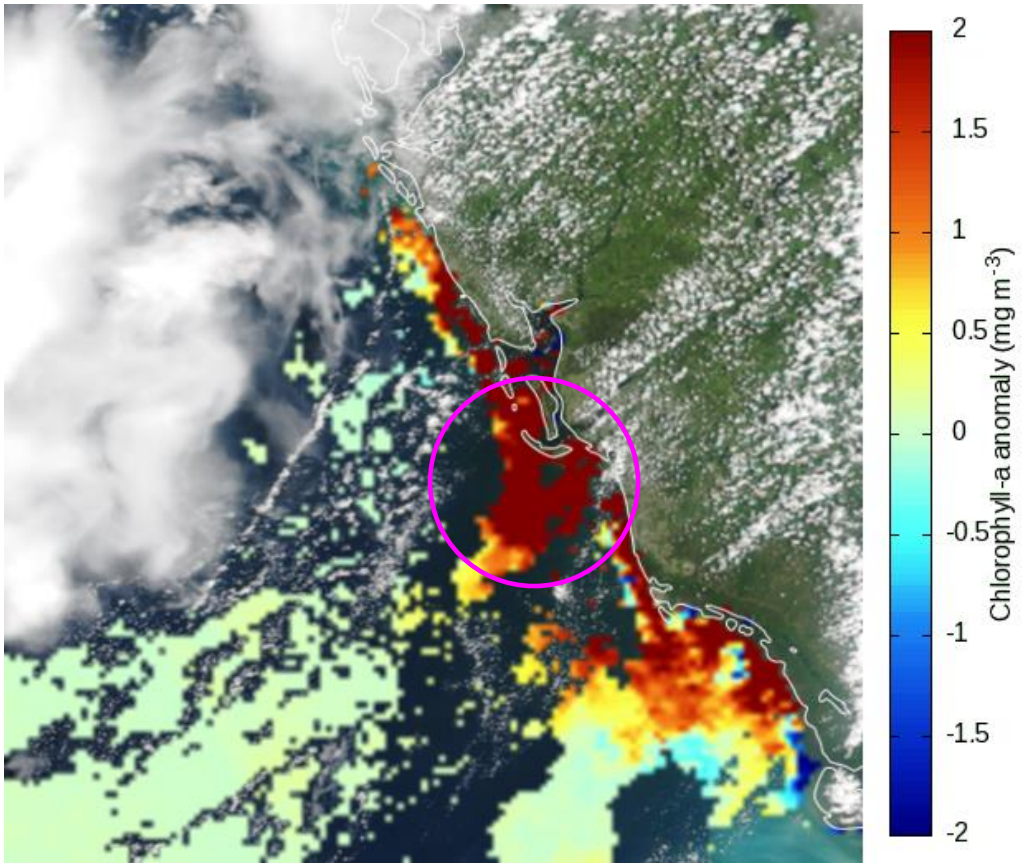
-2 -1.5 -1 -0.5 0 0.5 1 1.5 2

2018-07-26

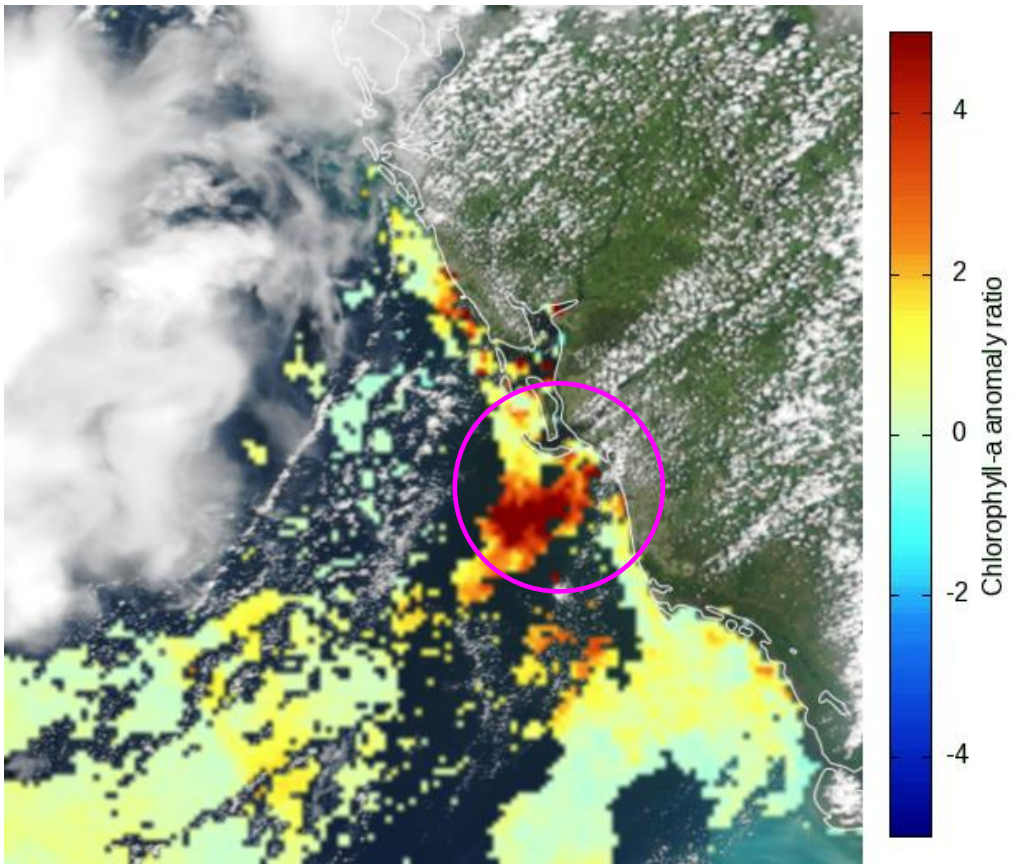
Global daily NRT Chl-a anomaly and anomaly ratio are *Routinely* produced

Menghua Wang, NOAA/NESDIS/STAR

High Chl-a Anomaly Linked to HAB in the West Coast of Florida (July 26, 2018)



Chl-a Anomaly



Chl-a Anomaly Ratio

Global NRT Chl-a anomaly and anomaly ratio are routinely produced

Menghua Wang, NOAA/NESDIS/STAR

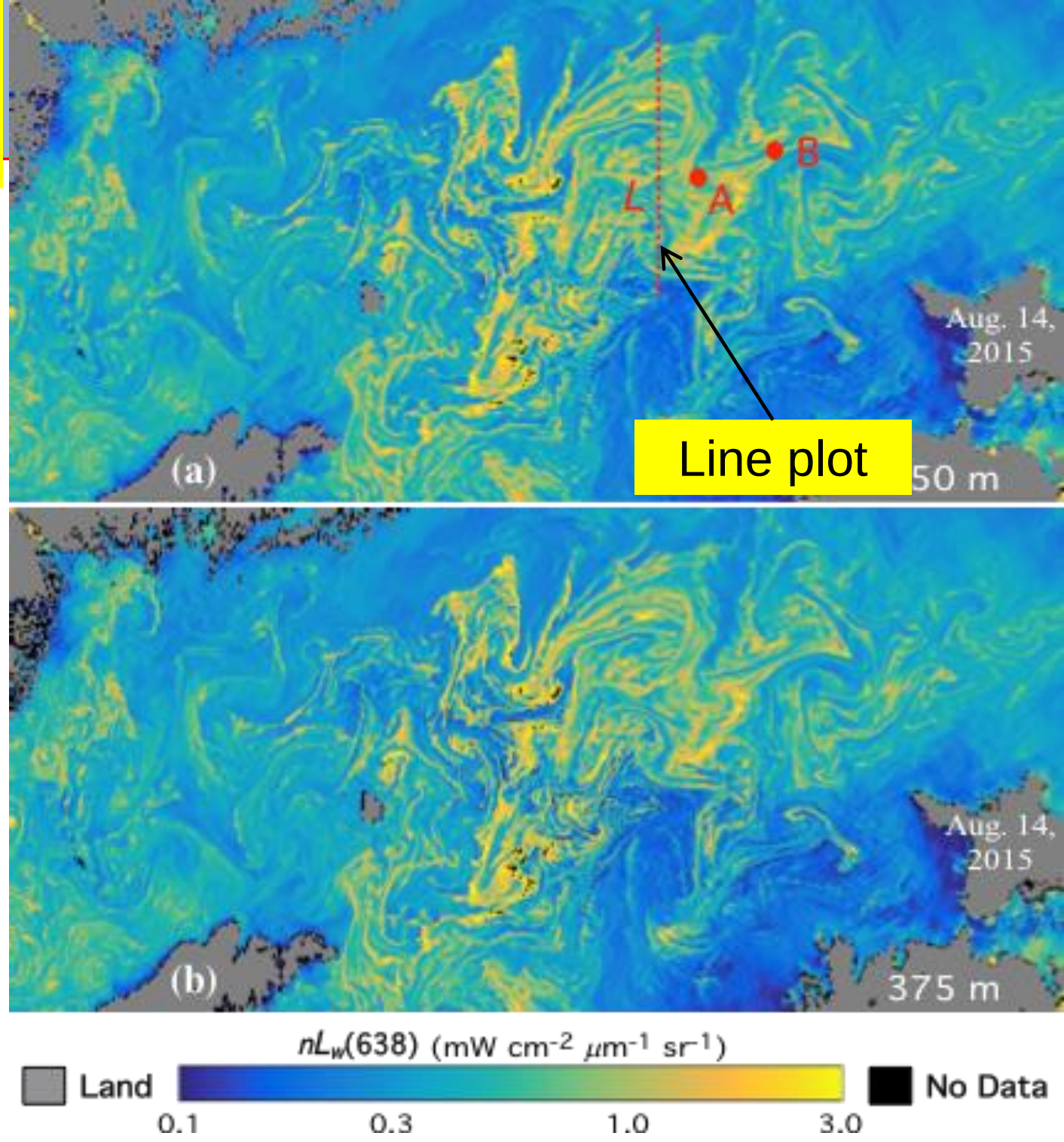
New VIIRS $nL_w(638)$ with Imaging Bands

(Resolution at 375 m)

Example:

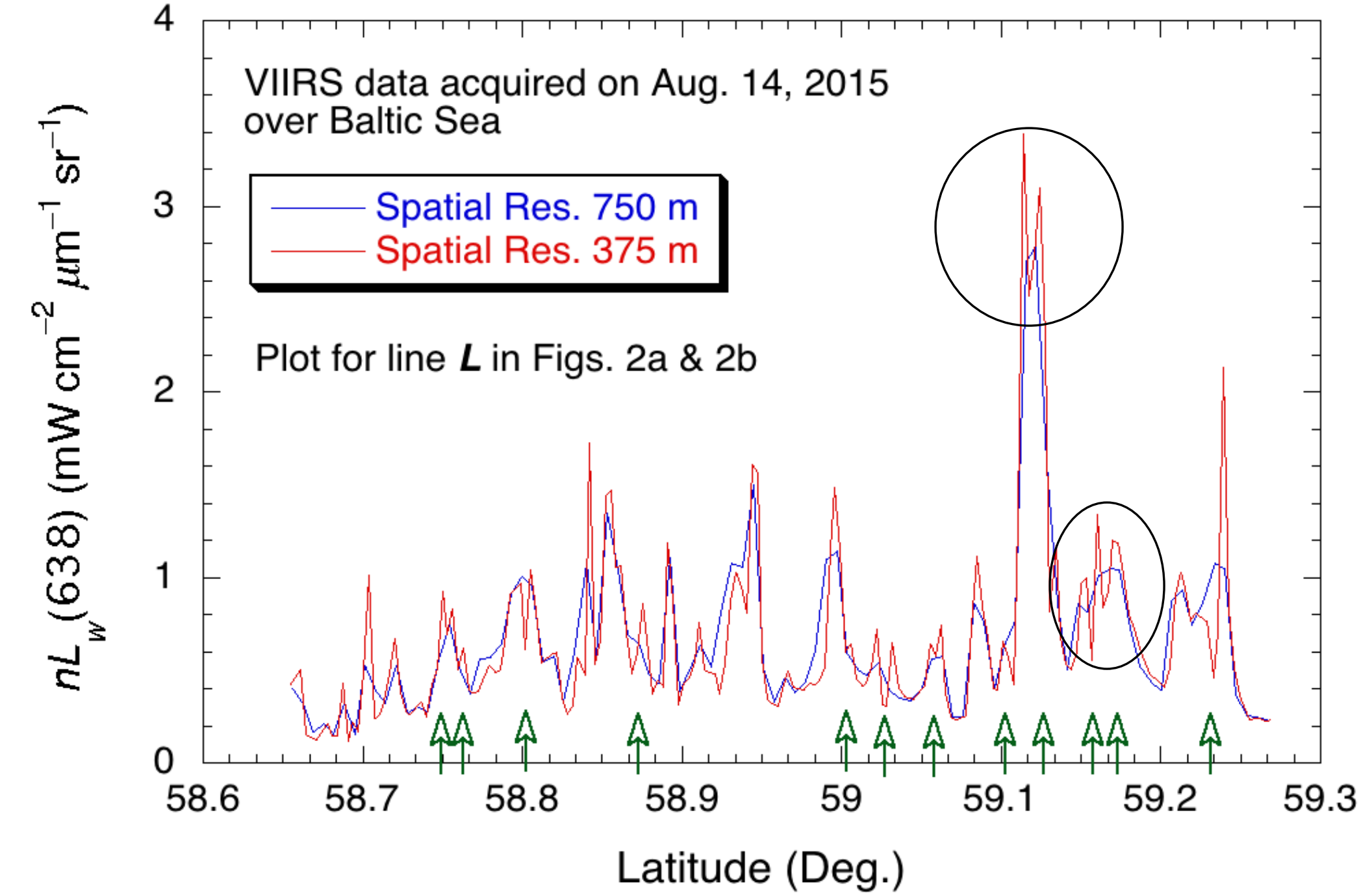
Algae Bloom in the Baltic Sea on August 14, 2015

One can see differences between two images for bloom size < ~500 m, showing high spatial resolution data providing more details for bloom spatial distribution/features

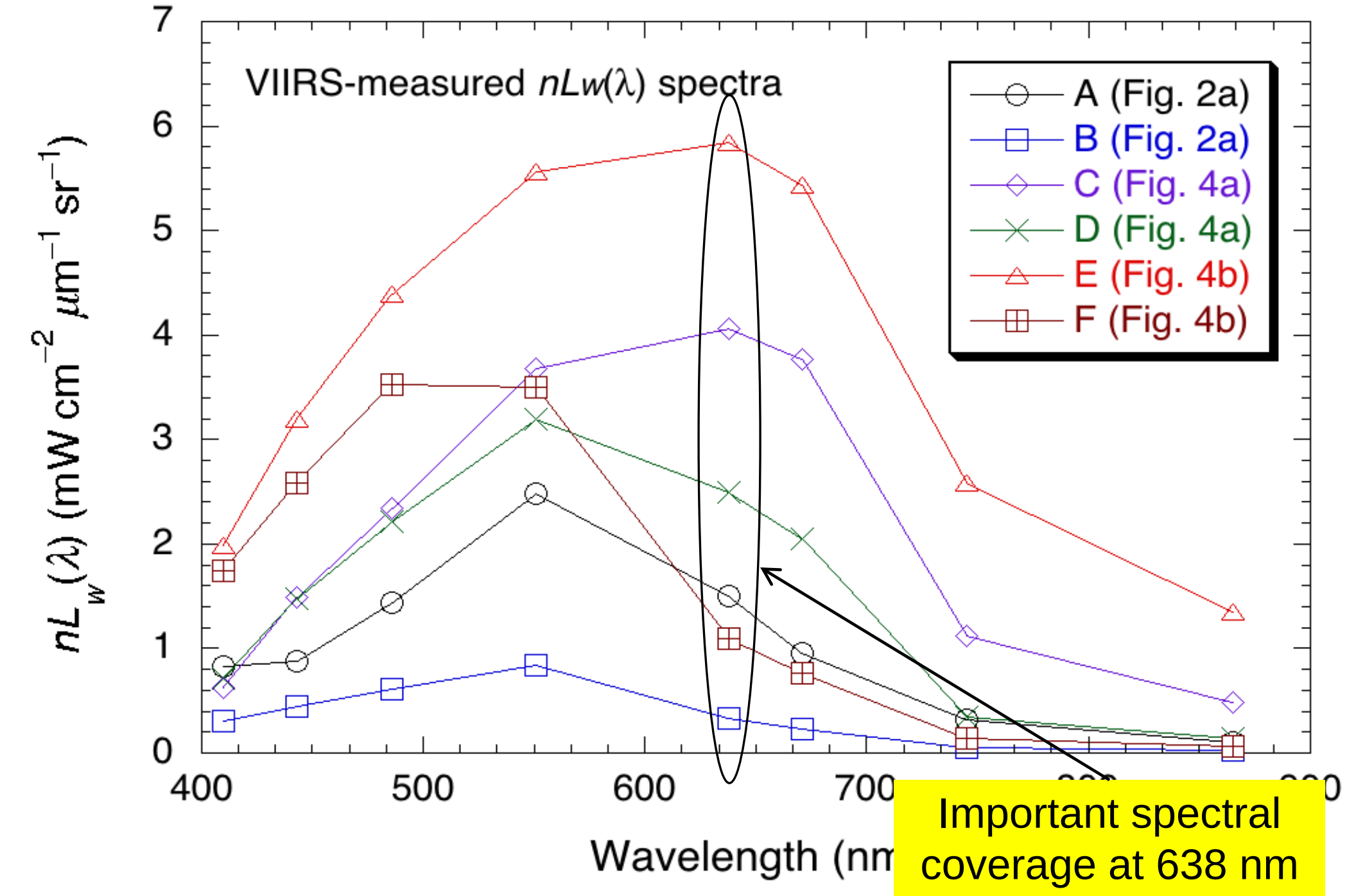


Wang, M. and L. Jiang (2017), "VIIRS-derived ocean color product using the imaging bands", *Remote Sen. Environ.*, **206,** 275–286, 2018. http://dx.doi.org/10.1016/j.rse.2017.12.042

More Detailed Algae Bloom Information Provided by VIIRS High Spatial Resolution (375 m) $nL_w(638)$ Data



Increased spectral coverage with VIIRS new $nL_w(638)$ data, providing important spectral information



Two Data Streams for VIIRS Ocean Color EDR

To meet requirements from **All** users (operational, research, modeling, etc.), we have been routinely producing VIIRS global ocean color products in **two data streams**: Near-Real-Time (NRT) and Delayed Science-Quality data.

Attribute	Near-Real Time (NRT)	Delayed Science-Quality
Latency:	Best effort, as soon as possible (~12-24h)	Best effort, on 1-2-week delay
Processing System:	MSL12	MSL12
SDR:	IDPS Operational SDR	OC-Improved SDR
Ancillary Data:	Global Forecast System (GFS) Model	Science quality (assimilated; GDAS) from NCEP
Coverage:	May have gaps due to various issues	Complete global coverage
Processed by:	NOAA CoastWatch, transferring to OSPO (operational)	NOAA/STAR
Distributed by:	NOAA CoastWatch, OSPO	NOAA CoastWatch, NCEI
Archive Plans:	Yes, from OSPO to NCEI	Yes, from CoastWatch to NCEI
Full Mission Reprocessing:	No	Yes, every ~2-3 years or as needed

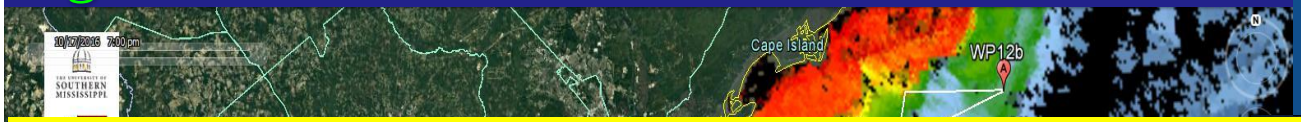
NOAA Capability of End-to-End Ocean Color Data Processing

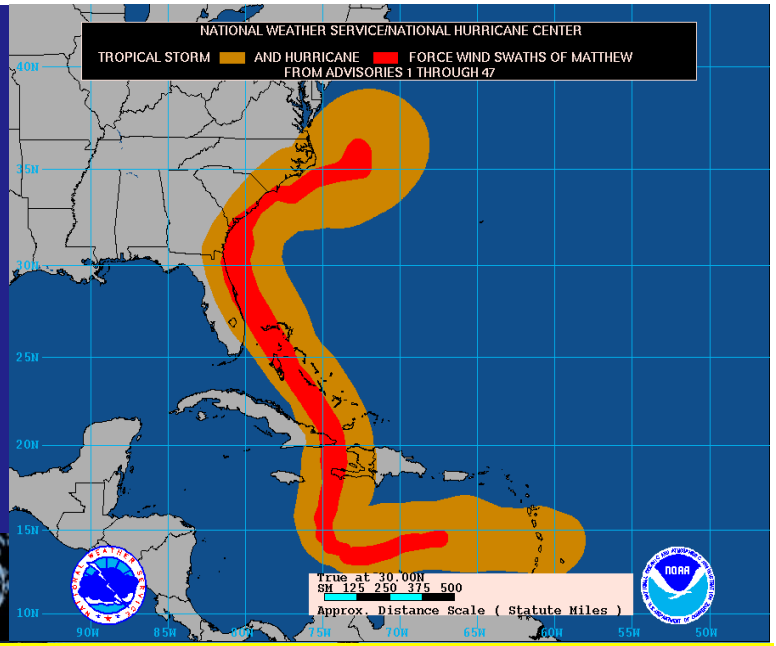
- NOAA Ocean Color Team has been developing/building the capability for the **End-to-End** satellite ocean color data processing including:
  - Level-0 (or Raw Data Records (RDR)) to Level-1B (or Sensor Data Records (SDR)).
  - **Level-1B (SDR) to ocean color Level-2 (Environmental Data Records (EDR) 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** ….,)
- **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.
- **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.
- **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.
- **O**cean **C**olor **D**ata **A**nalysis and **P**rocessing **S**ystem (**OCDAPS**)—IDL-based VIIRS ocean color data visualization and processing package
  - Wang, X., X. Liu, L. Jiang, M. Wang, and J. Sun, "VIIRS ocean color data visualization and processing with IDL-based NOAA-SeaDAS", *Proc. SPIE 9261*, 8 Nov. 2014.
- **Work with users to meet their requirements.**

Dedicated VIIRS Cal/Val Cruise III
NOAA Ship *Nancy Foster*
5-18 October 2016

NOAA, NRL, NASA, USF, UMB, CUNY, IDEO, OSU

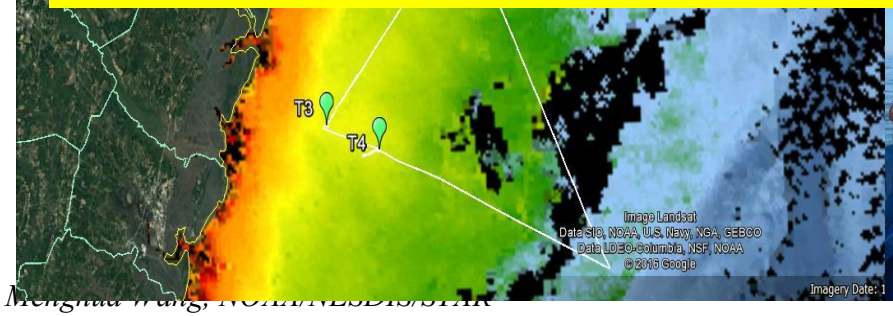
Measurements done just after Hurricane Matthew in the region **13-18 October 2016.**

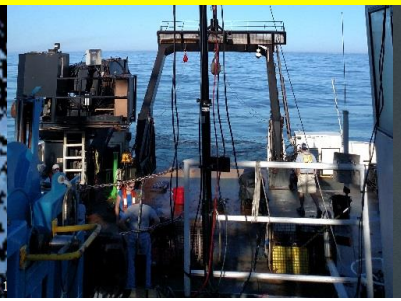


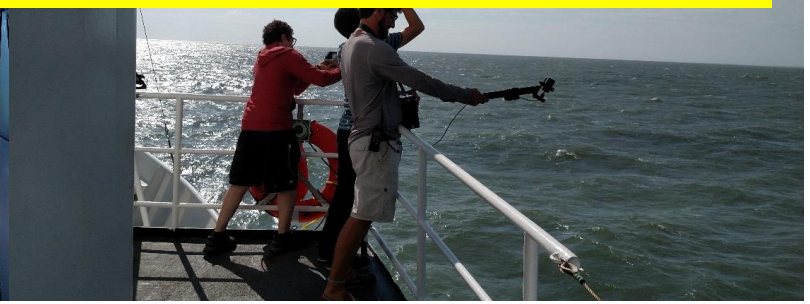


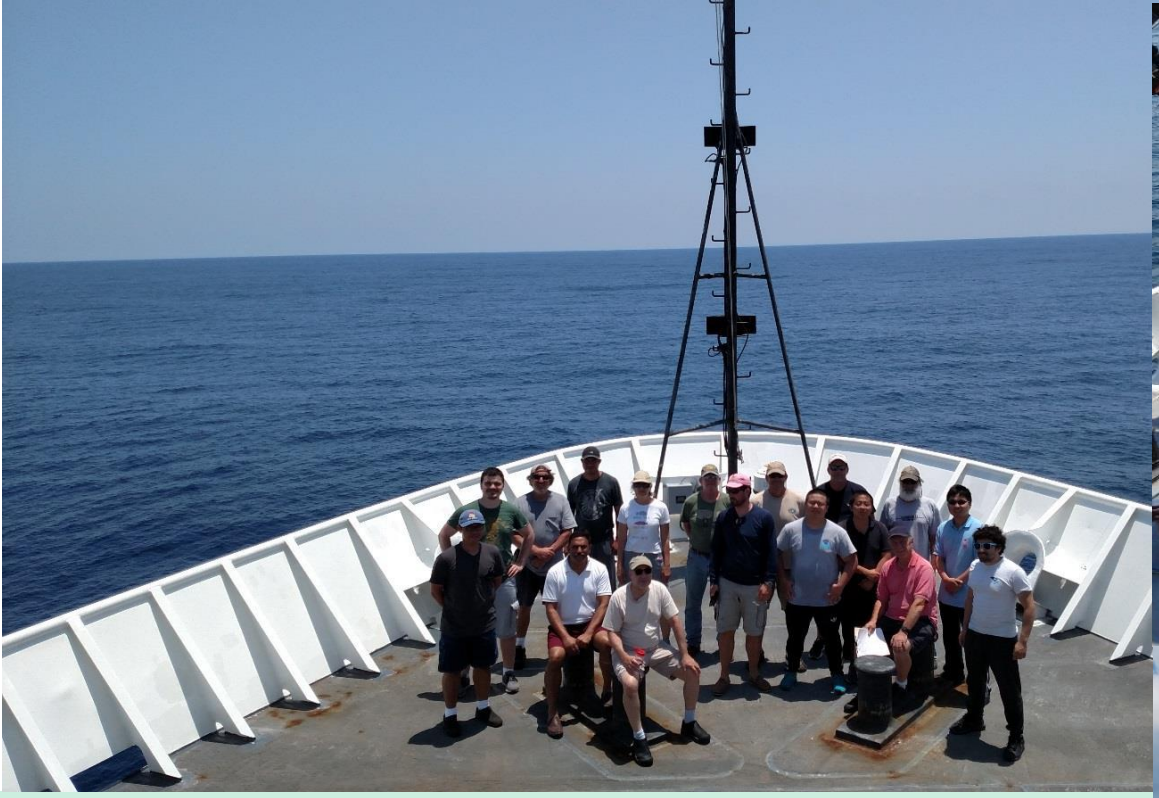
Ondrusek, M., V. P. Lance, M. Wang, E. Stengel, C. Kovach, R. Arnone, S. Ladner, W. Goode, A. Gilerson, S. Ahmed, A. El-Habashi, R. Foster, M. Ottaviani, J. I. Goes, H. Gomes, K. McKee, J. W. Kang, C. Hu, J. Cannizzaro, S. Sun, D. English, B. C. Johnson, Z. P. Lee, L. Zoffoli, J. Lin, N. Tufillaro, I. 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. http://dx.doi.org/10.7289/V5/TR-NESDIS-151

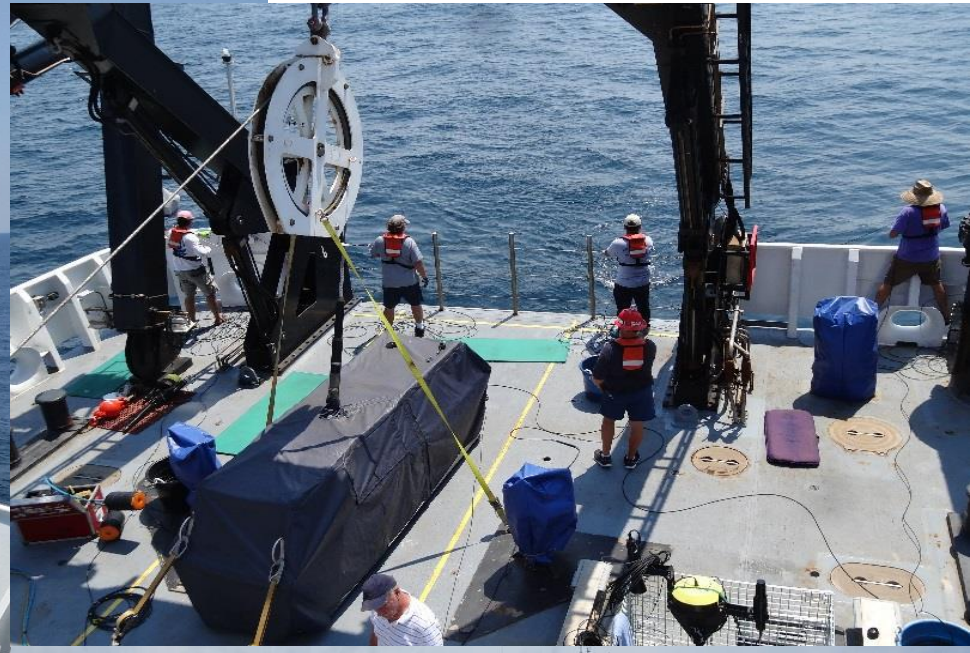
Published other Cal/Val cruise reports (2014 and 2015)







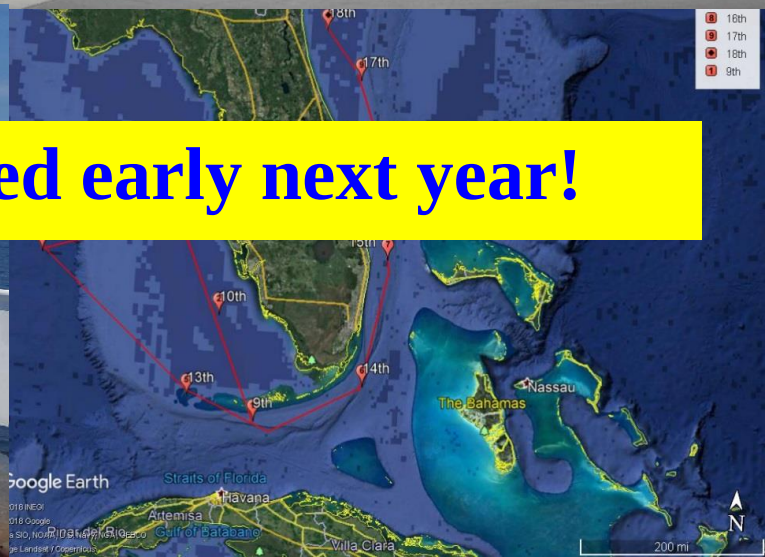




Dedicated VIIRS Cal/Val Cruise IV

NOAA Ship *Okeanos Explorer*

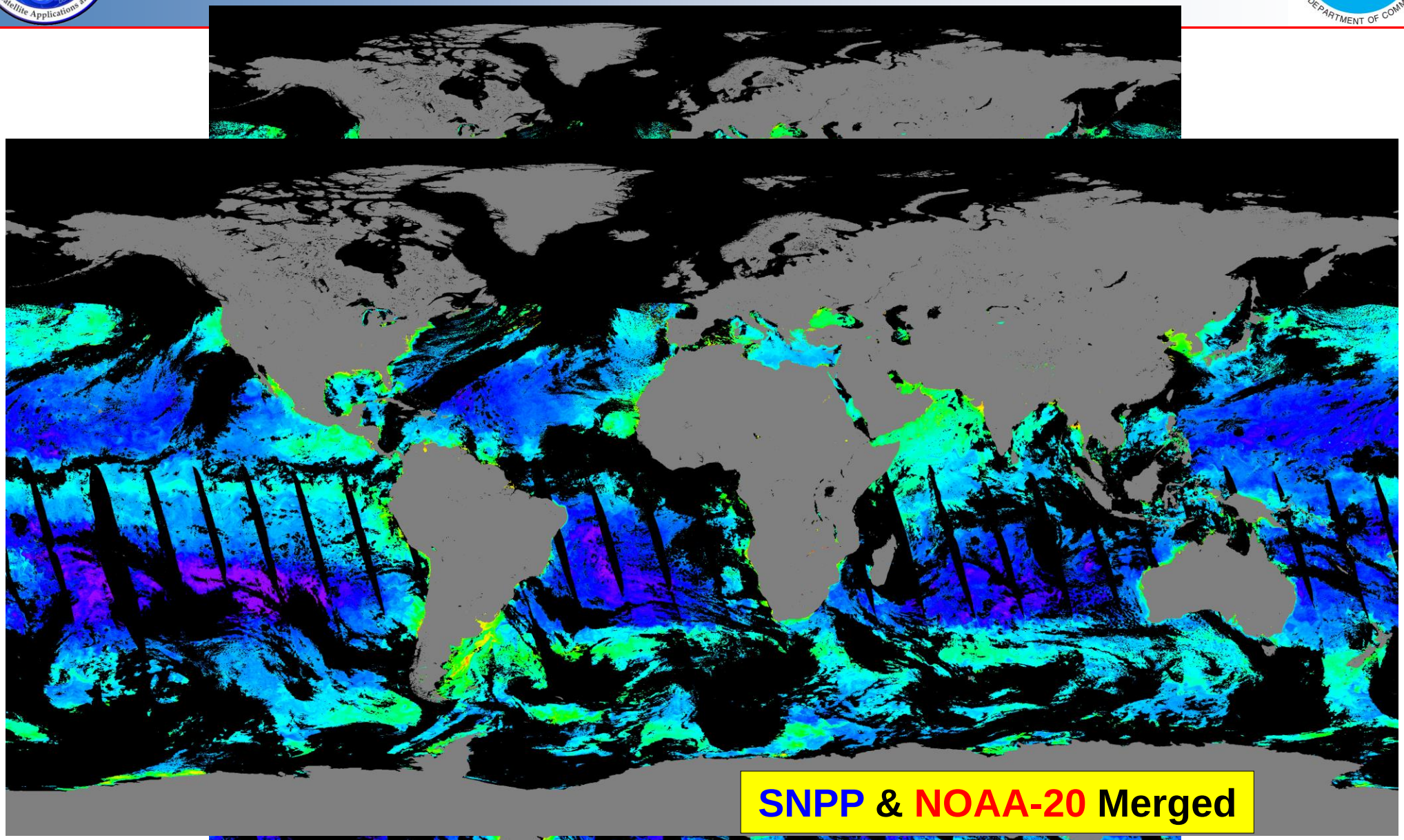
9-18 May 2018



Cal/Val cruise report will be published early next year!

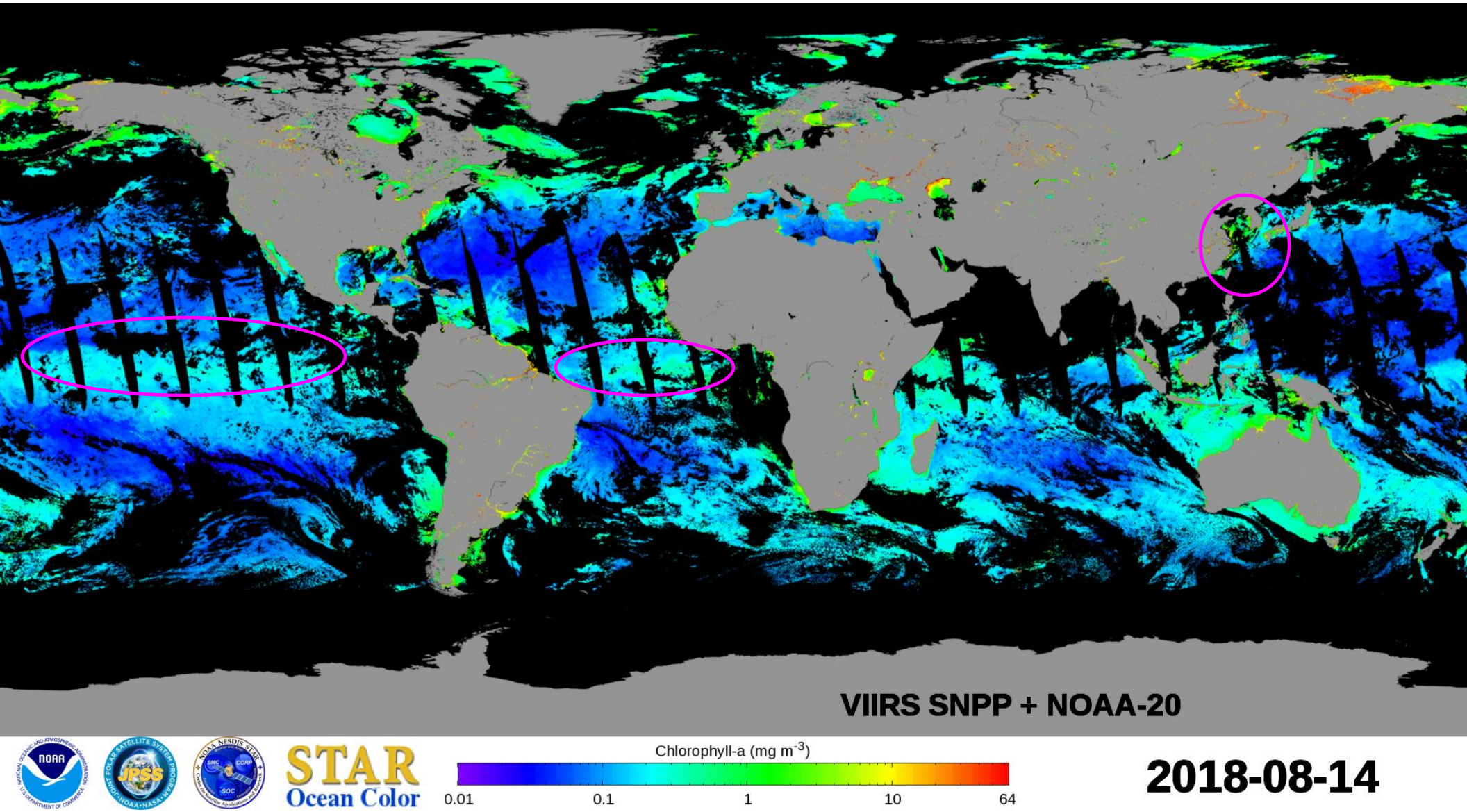
VIIRS-SNPP and NOAA-20 Chl-a Images

(January 6, 2018)



Menghua Wang, NOAA/NESDIS/STAR

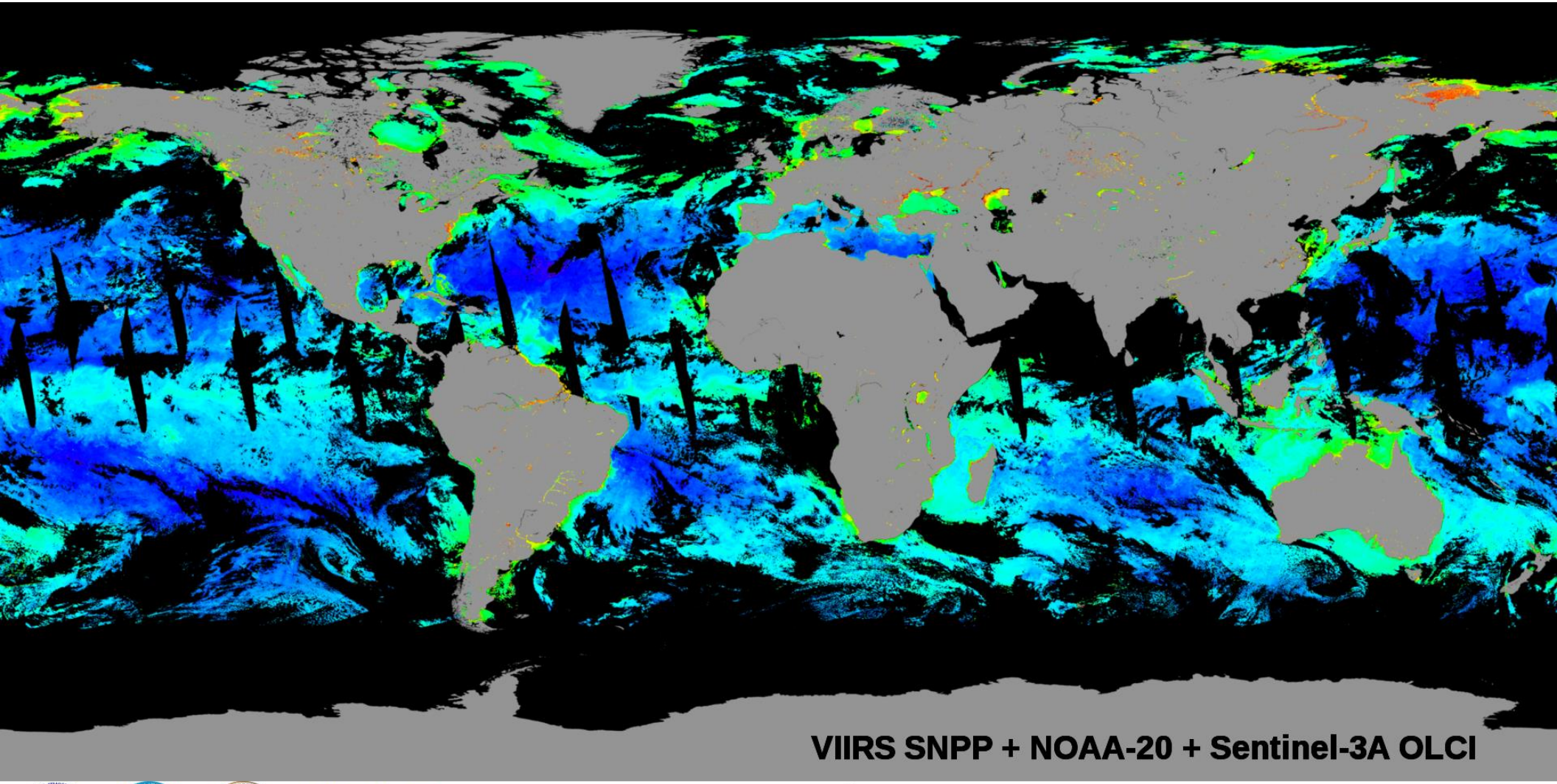
VIIRS SNPP and NOAA-20 Merged Global Chl-a
(August 14, 2018)



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

Menghua Wang, NOAA/NESDIS/STAR

VIIRS SNPP, NOAA-20, Sentinel-3A OLCI Merged Global Chl-a (August 14, 2018)



Ocean color data from the THREE sensors are all derived using the same MSL12!

Menghua Wang, NOAA/NESDIS/STAR

Matchup of

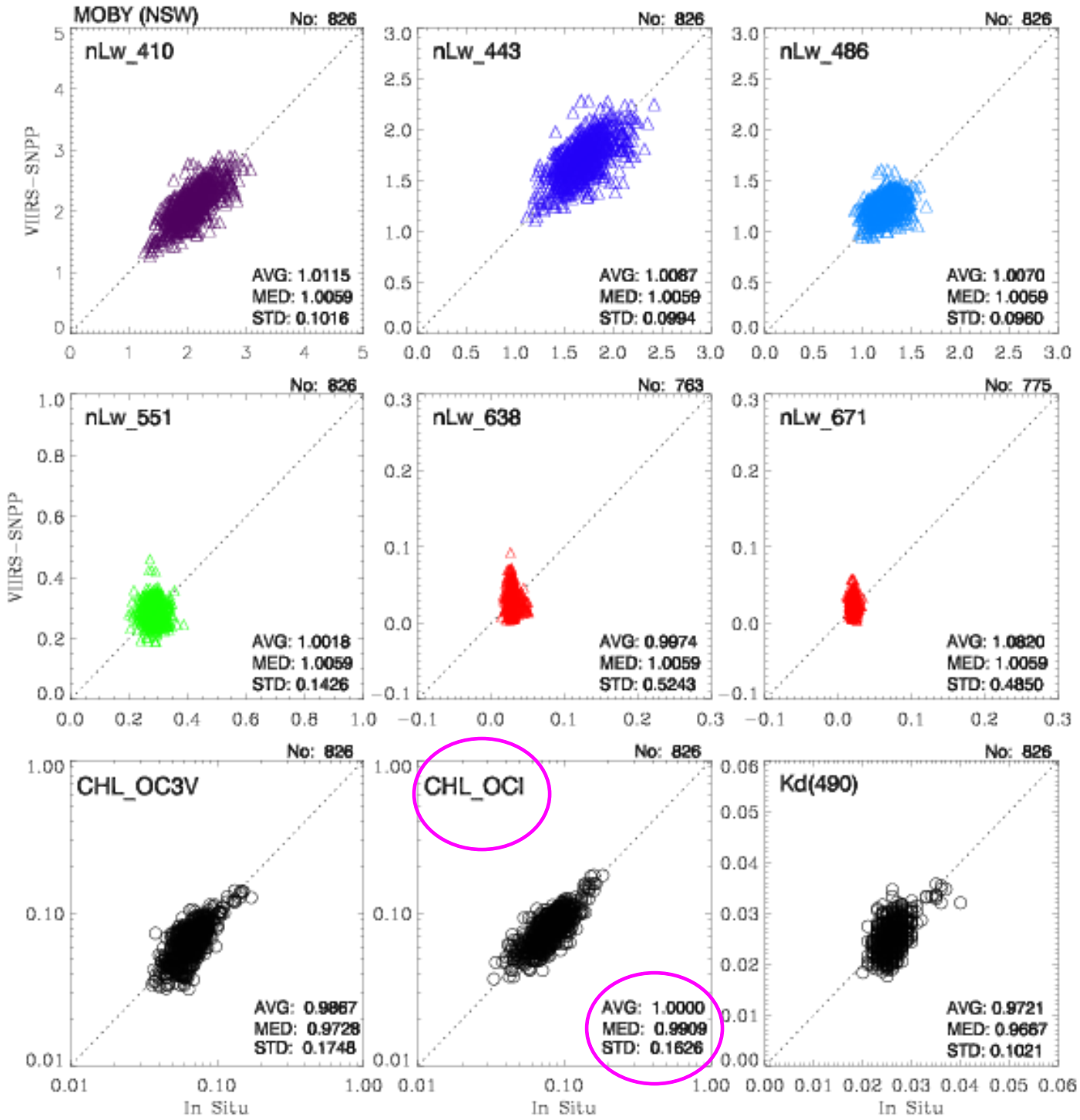
MOBY In Situ

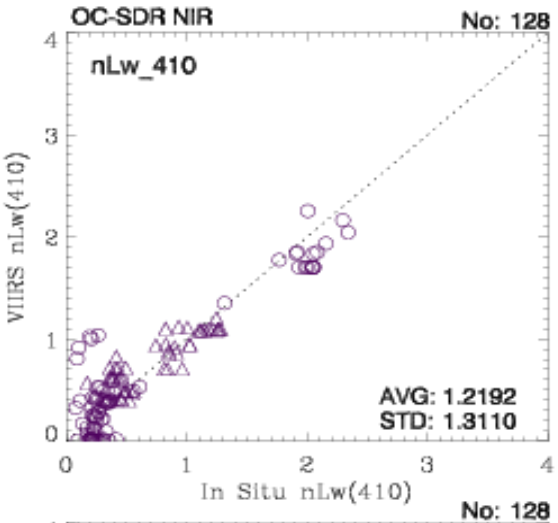
&

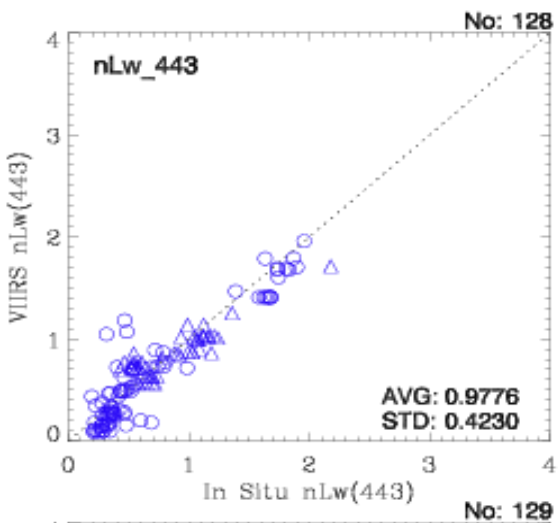
VIIRS-SNPP

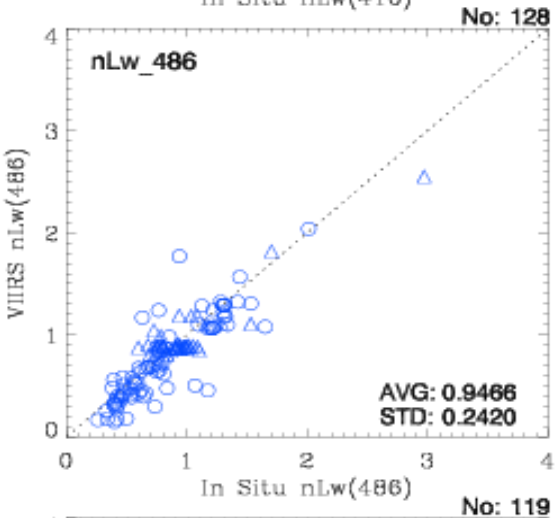
(NIR-SWIR)

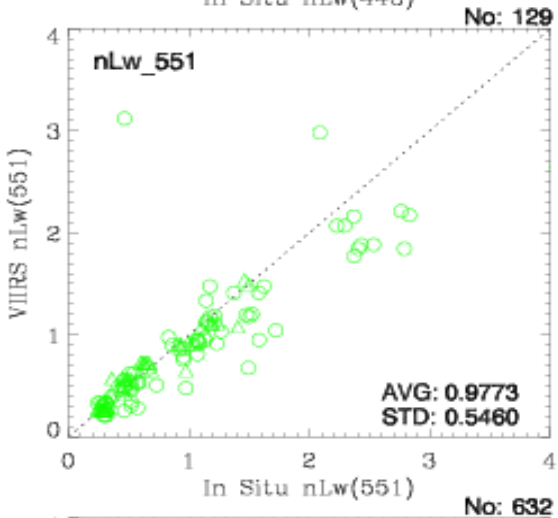
MOBY

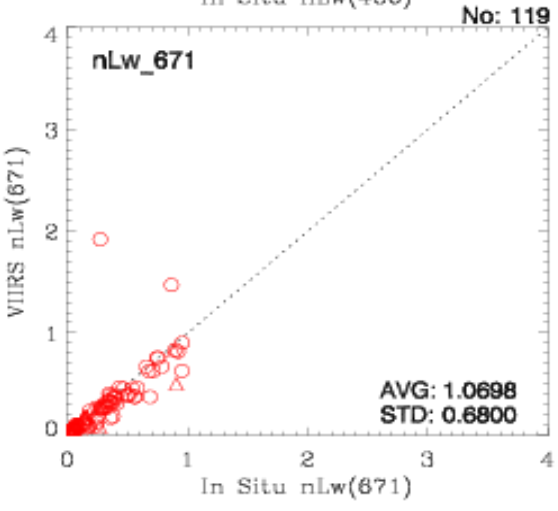


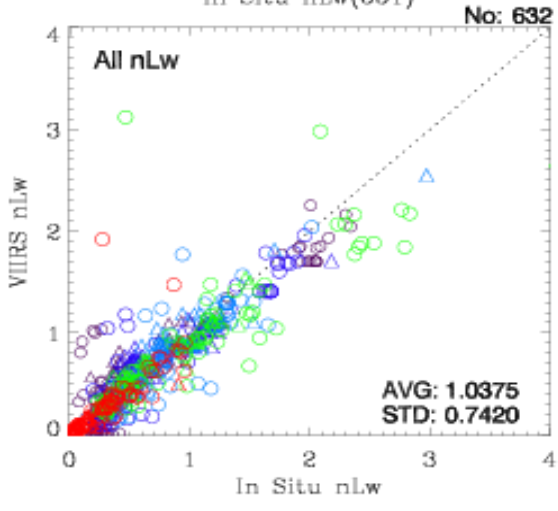












Validation Effort

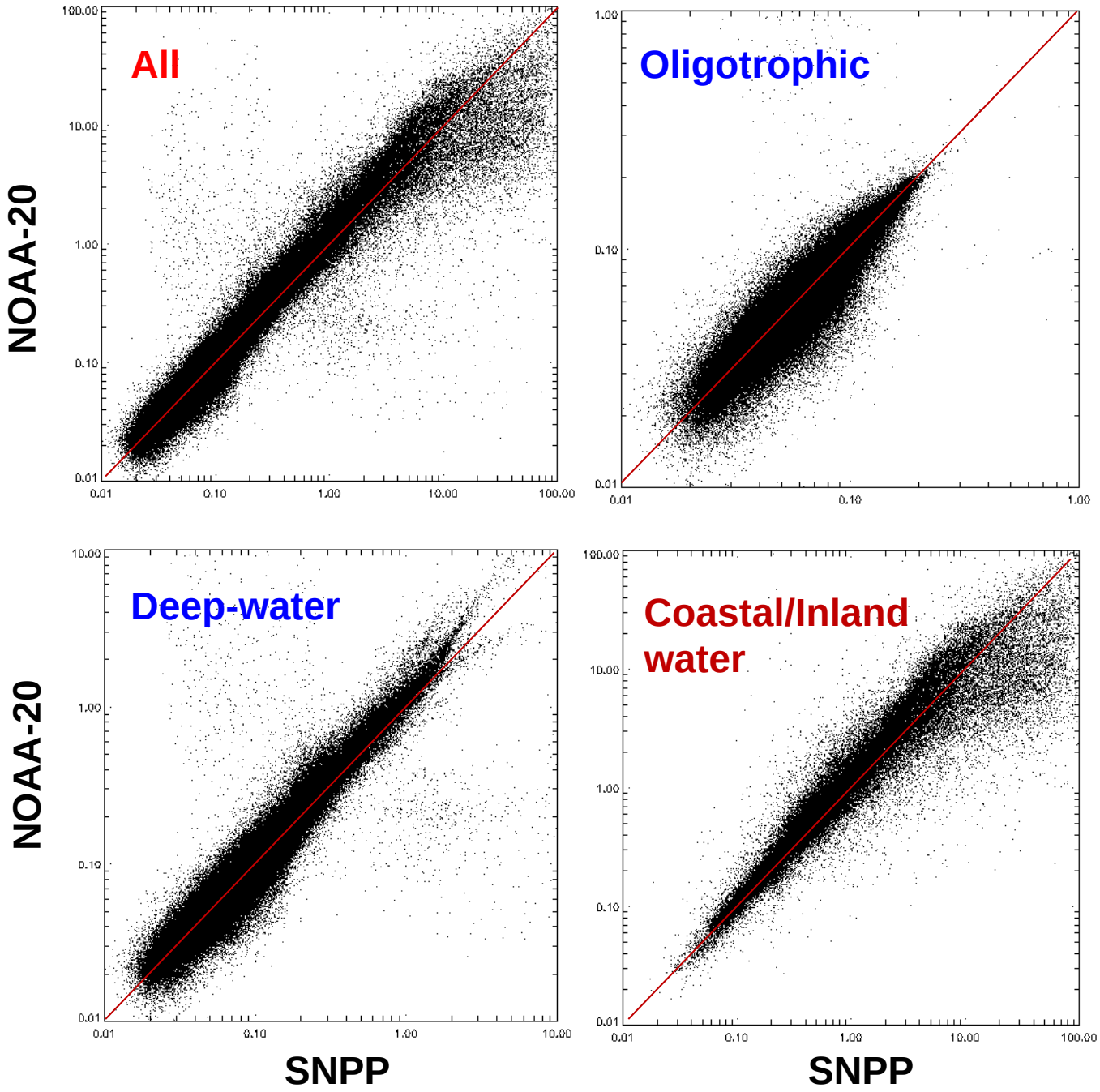
VIIRS-SNPP vs. In Situ Data

In Situ Data Sources:

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

VIIRS Global Chl-a Comparisons of NOAA-20 vs. SNPP (June 1, 2018)



VIIRS Ocean Color Side Meeting

Tuesday, 28 August 2018,

NCWCP 1st Floor Conference Room (A+B)

	Ocean Color - OC VIIRS EDR			Blue text = Update as needed
0915-1045		***Duration (min)***		
	915	30	Wang, Menghua	Welcome and Overview of MSL12 and Ocean Color EDR Team activities
	945	15	Sun, Junqiang	VIIRS OC calibration update
	1000	15	Liu, Xiaoming	New merged products
	1015	15	Mikelsons, K.	New capabilities of OCView--Online display and monitoring of ocean color product imagery
	1030	15	Zhaohui Cheng	Operational (near real-time) OC update
	1045	15	**BREAK (15 min)**	
1100 - 12(	***Ocean Color - VIIRS EDR Cal/V(***			*PI's should include status of publications related to VIIRS cruises*
	1100	15	Voss, K. (U. Miami)	Update on MOBY-Refresh and MOBY products
	1115	15	Ondrusek, M. (NOA	Cruise(s) Overview and Optical in situ Validation
	1130	15	Arnone, R. (Stennis)	Evaluation of VIIRS ocean color products and development of enhanced ocean products and applications
	1145	15	Gilerson, A. (CCNY)	CCNY VIIRS validations at the Long Island Sound Coastal Observatory (LISCO) and on cruises
1200-131!	**LUNCH (75 min)**			
1315 - 14:	***Ocean Color - VIIRS EDR Cal/V(***			*PI's should include status of publications related to VIIRS cruises*
	1315	15	Hu, C. (USF)	Evaluation of VIIRS performance in coastal waters and in its capacity to detect dark water and harmful algal blooms
	1330	15	Lee, Z. (UMB)	Towards consistent VIIRS AOP and IOP products
	1345	15	Tufillaro, N. (OSU); Jones, B./Ragan, M. (USC)	Validation of VIIRS ocean color products for the US West Coast
	1400	15	Carol Johnson (NIST)	NIST update
	1415	15	Joaquim Goes (LDEO)	Phytoplankton physiology/functional types
1430-151!	***Ocean Color- OC VIIRS in situ program***			
	1430	20	Lance, V-	Cruise reports, Cruise data sharing policy at NOAA; NCEI archiving of cruise data (by cruise); in situ Ocean Color Optical Database at NOAA
	1450	25	Facilitator: Ondrusek, M. (NOAA/STAR)	Group Discussion: May 2019 (FY19) cruise planning/ lessons learned from previous cruises.
1515-153(	**BREAK (15 min)**			
1530 - 17(	***Ocean Color - Users, New Applications, Data Distribution***			
	1530		Daniel Tong, OAR/ARL	Isoprene emissions from VIIRS ocean color informs air quality forecasts
	1545	15	Eric Geiger, Coral Reef Watch	Coral Reef Watch use and applications for ocean color data products
	1600	15	Yongsheng Zheng	NCEI Scientific Stewardship on NOAA MSL12 Ocean Color EDR Products
	1615	15	Lance, V. (CoastWatch)	Ocean Color Data distribution through NOAA CoastWatch/OceanWatch and NCEI
	1630	30	Menghua Wang	Questions, discussion, plans for next year
1700	**ADJOURN SJASM**			

Conclusions

- VIIRS-SNPP and VIIRS-NOAA-20 global ocean color products have been routinely produced using the **NIR**-, **SWIR**-, and **NIR-SWIR**-based atmospheric correction algorithms, providing necessary satellite data for various applications in open oceans, coastal and inland waters, as well as for further improving data quality.
- Our evaluation results show that VIIRS-SNPP can produce high quality ocean color data over global open oceans and reasonable data quality over coastal and inland waters.
- VIIRS-NOAA-20 can also produce reasonable ocean color data quality, and ocean color results are generally comparable to those from VIIRS-SNPP.
- However, there are still some issues/problems, including NOAA-20 SDR calibration problems that significantly impact VIIRS ocean color data quality.
- VIIRS-NOAA-20 mission-long ocean color data **reprocessing** is current underway due to IDPS SDR calibration errors and error in early polarization correction.
- Significant effort is still needed for improving ocean color data quality over turbid coastal and inland waters.

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

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

Thank You!