International Ocean Colour Science Meeting 2017

NOAA OCEAN COLOR ACTIVITIES

Menghua Wang &

NOAA Ocean Color Team

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

IOCS Meeting, Lisbon, Portugal, 15-18 May 2017

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

Acknowledgements: VIIRS 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	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, Ryan Vandermeulen Adam Lawson, Paul Martinolich, 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
	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.

VIIRS Spectral Bands for Ocean Color

VIIRS (Visible Infrared Imaging Radiometer Suite) on
Suomi National Polar-orbiting Partnership **(SNPP)**
VIIRS-**SNPP**, Oct. 28, **2011**, VIIRS-Joint Polar Satellite System (**JPSS**) **J1**, **2017**, VIIR-**J2**,
2021, and J3 & J4 (up to ~2038)

VIIRS†		MODIS		SeaWiFS
Ocean Bands (nm)	Other Bands (nm)	Ocean Bands (nm)	Other Bands (nm)	Ocean Band (nm)
410 (M1)	638 (I1)	412	645	412
443 (M2)	862 (I2)	443	859	443
486 (M3)	1600 (I3)	488	469	490
—		531	555	510
551 (M4)	*SWIR Bands*	551	*SWIR Bands*	555
671 (M5)	1238 (M8)	667	1240	670
745 (M6)	1601 (M10)	748	1640	765
862 (M7)	2257 (M11)	869	2130	865

†VIIRS-SNPP nominal center wavelength

Spatial resolution for VIIRS M-band: 750 m, I-band: 375 m

Summary of VIIRS Ocean Color EDR Products

- **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** (8):
  - 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), $K_d(PAR)$
  - Level-2 quality flags
- **Experimental Products**:

New added global products: ***nL_w(638)*** (I-band with 375 m), **QA Score**, and **Chl-a anomaly** and **Chl-a anomaly ratio**

  - Photosynthetically Available Radiation (PAR) (*R. Frouin*)
  - Chl-a from ocean color index (OCI) method (*Hu et al.*, 2012; *Wang and Son*, 2016)

We are open for adding new VIIRS global products

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

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---**measurement-based data processing system**.
  - 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, ….,)
- **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.**

Report for the 2014 NOAA dedicated Cal/Val cruise has been published!

NOAA Technical Report NESDIS 146

DOI: 10.7289/V52B8W0Z

Report for
Dedicated JPSS VIIRS Ocean Color
Calibration/Validation Cruise

Washington, D.C.
September 2015

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Dedicated VIIRS Cal/Val Cruises

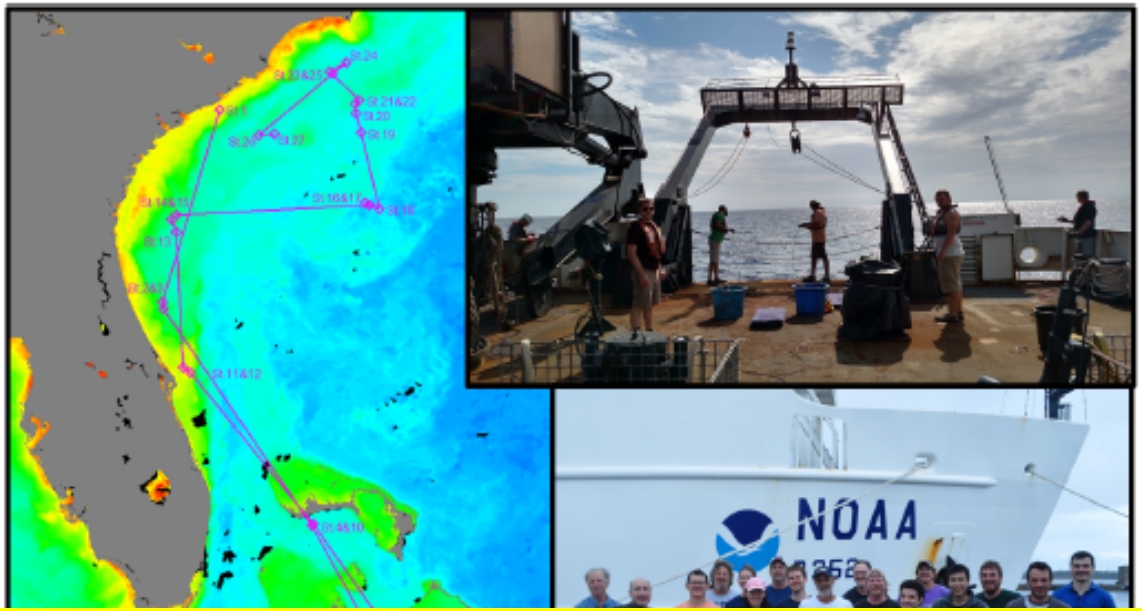
Ondrusek, M., E. Stengel, V. P. Lance, M. Wang, K. J. Voss, G. Zibordi, M. Talone, Z. P. Lee, J. Wei, J. Lin, C. Hu, D. English, C. Kovach, J. Cannizzaro, A. Gilerson, S. Ahmed, A. Ibrahim, A. El-Habashi, R. Foster, R. Arnone, R. Vandermeulen, S. Ladner, W. Goode, J. I. Goes, H. Gomes, A. Chekalyuk, 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. http://dx.doi.org/10.7289/V52B8W0Z

http://dx.doi.org/10.7289/V52B8W0Z

NOAA Technical Report NESDIS 148

doi:10.7289/V5/TR-NESDIS-148

Report for Dedicated JPSS VIIRS Ocean Color Calibration/Validation Cruise December 2015



Report for the 2015 NOAA dedicated Cal/Val cruise has been published!

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. http://dx.doi.org/10.7289/V5/TR-NESDIS-148

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

Two Data Streams for VIIRS Ocean Color EDR

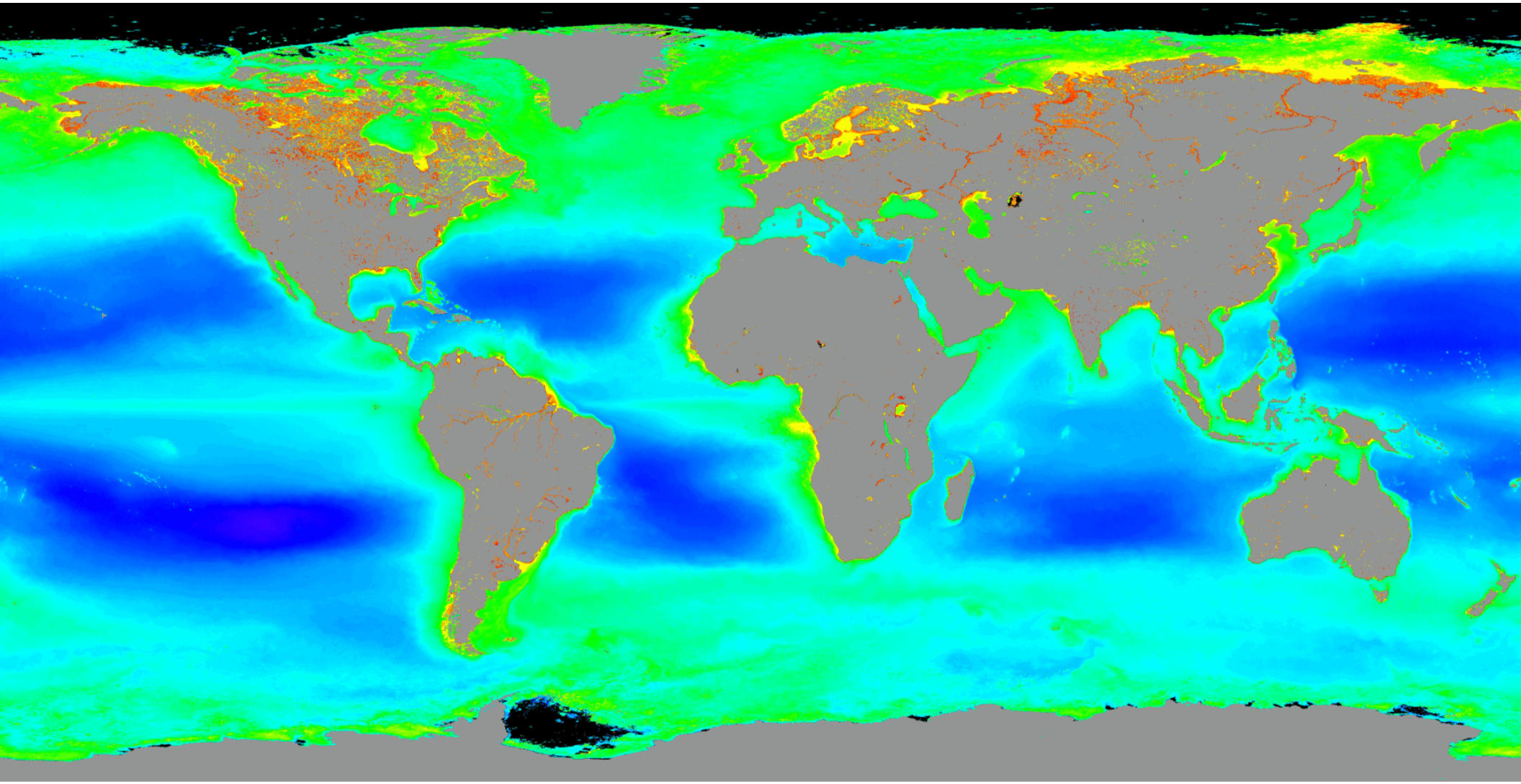
To meet requirements from **All** users (operational, research, modeling, etc.), we have been routinely producing VIIRS global ocean color products in **two data streams**: Near-Real-Time (NRT) and Delayed Science-Quality data.

Attribute	Near-Real Time (NRT)	Delayed Science-Quality
Latency:	Best effort, as soon as possible (~12-24h)	Best effort, on a 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
Spatial Coverage:	May be gaps due to various issues	Complete global coverage
Processed by:	CoastWatch, transferring to OSPO (operational) FY16	NOAA/STAR
Distributed by:	CoastWatch, OSPO	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

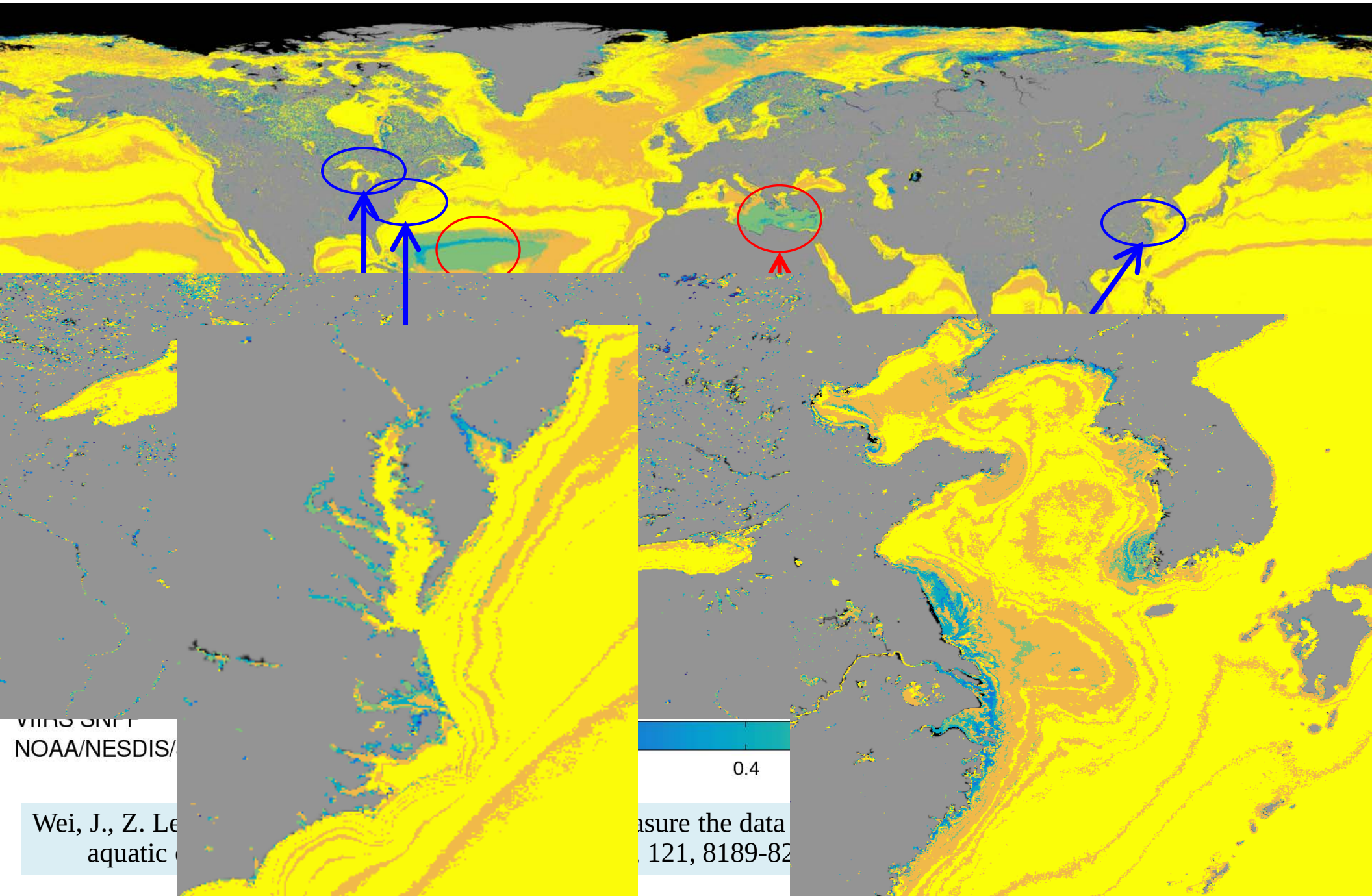
VIIRS Mission-long Ocean Color Data Reprocessing

- ✓ We have recently reprocessed VIIRS mission-long ocean color data products for the Science Quality data stream in April 2017. This is the second data reprocessing due to some significant improvements (algorithms and SDR). The first VIIRS mission-long OC data reprocessing was completed in May 2016. The science quality data stream has been going forward routinely.
- ✓ For the Science Quality data stream, VIIRS mission-long SDR has been reprocessed using significantly improved on-orbit calibration (both **solar** and **lunar** approaches).
- ✓ VIIRS ocean color data are available through CoastWatch. In particular, the Science Quality data stream will also be distributed through **CoastWatch** and NCEI.
- ➢ The reprocessed VIIRS mission-long Science Quality ocean color data have been significantly improved, providing accurate and consistent ocean color data for science research and applications. It shows the importance of the lunar data for calibration, particularly in recent years (and forwarding).
- ➢ VIIRS chlorophyll-a (Chl-a), $K_d(490)$, $K_d(\mathrm{PAR})$, $nL_w(410)$, $nL_w(443)$, $nL_w(486)$, $nL_w(551)$, and $nL_w(671)$, as well as I-band $nL_w(638)$ data are routinely produced now using the Multi-Sensor Level-1 to Level-2 (**MSL12**) ocean color data processing system.
- ➢ We show VIIRS global climatology ocean color product images, as well as some evaluation/validation results.

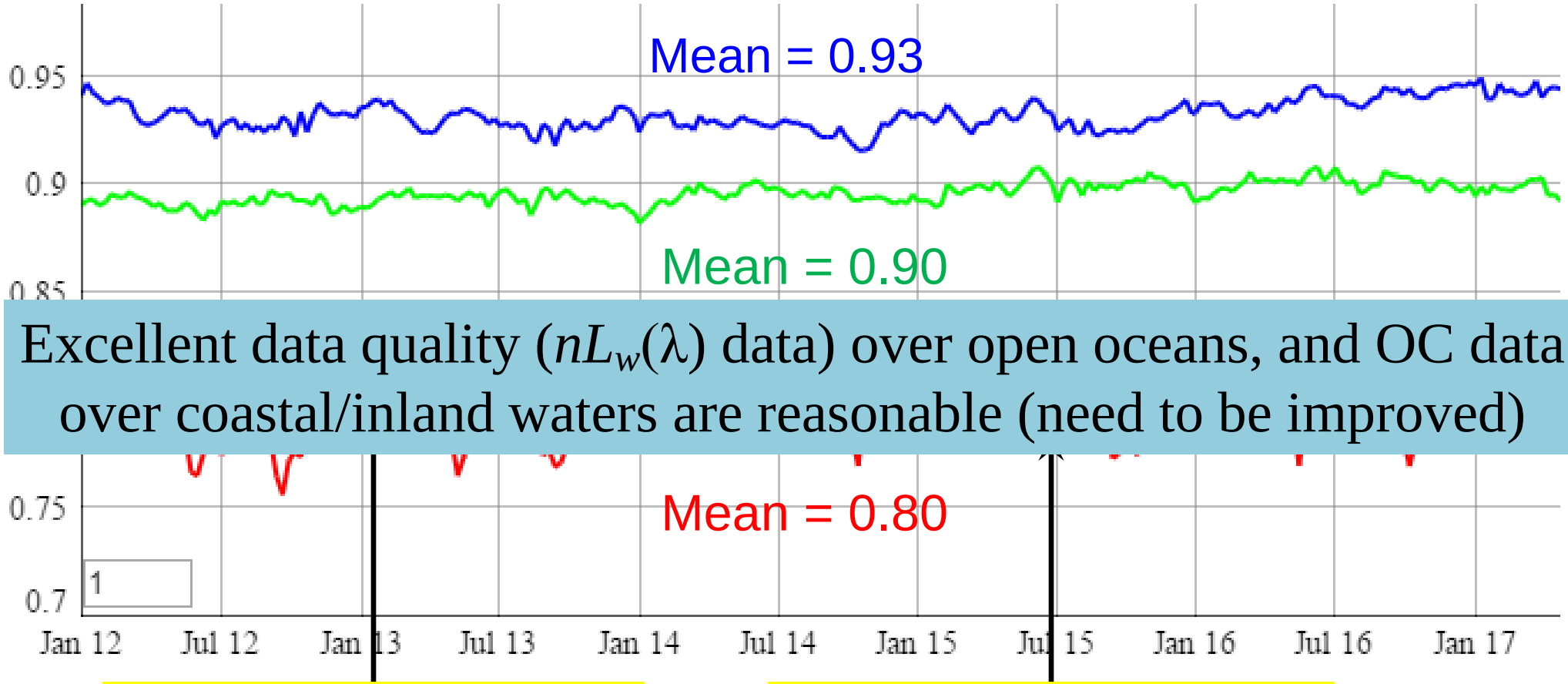
VIIRS Climatology Ocean Color Product Image (2012–2016)



VIIRS Climatology $nL_w(\lambda)$ QA Score Image (2012–2017)



VIIRS Mission-long QA Score
(global 8-day mean value)



Excellent data quality ($nL_w(\lambda)$ data) over open oceans, and OC data over coastal/inland waters are reasonable (need to be improved)

Higher score in winter

Lower score in summer

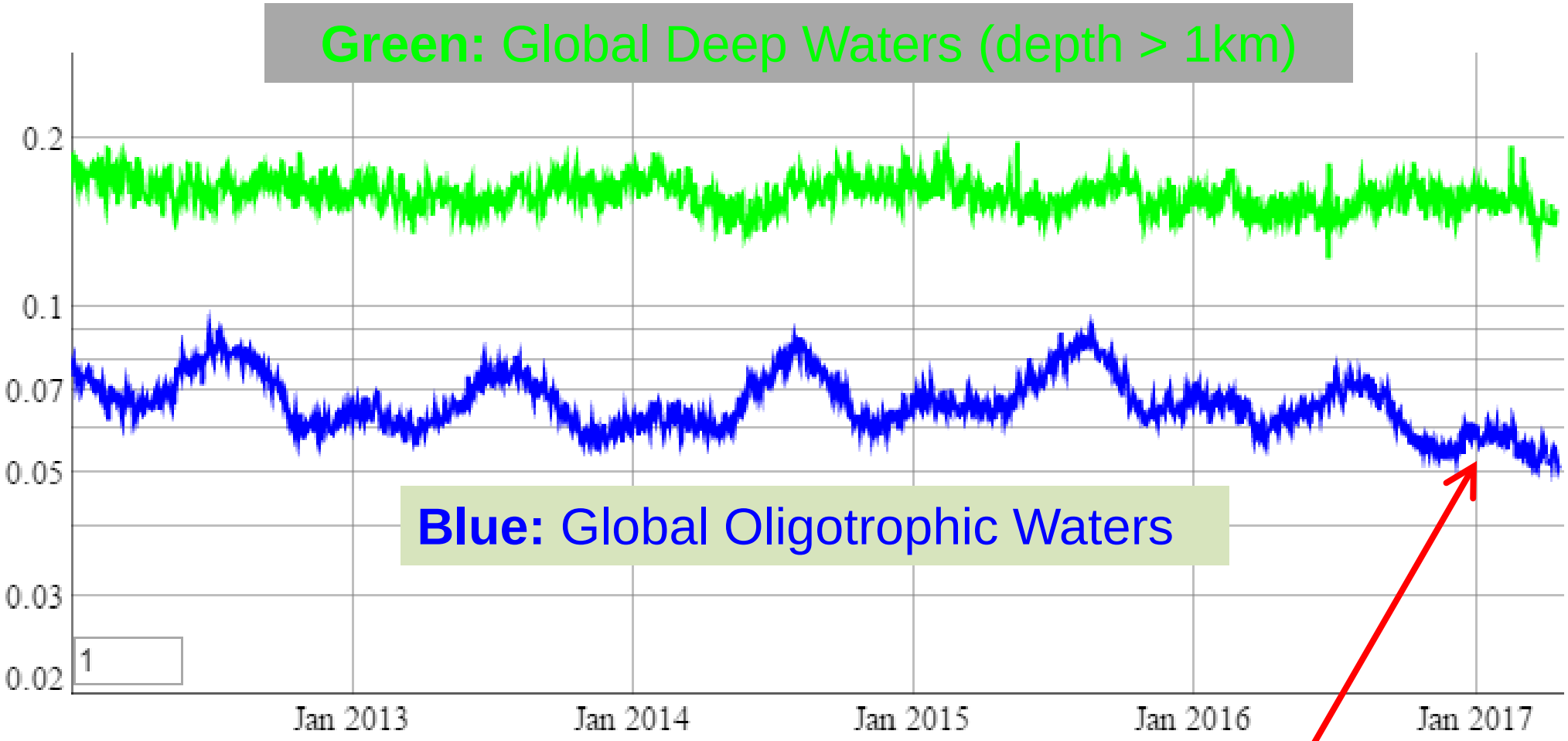
Blue: Global Oligotrophic Waters

Green: Global Deep Waters (depth > 1km)

Red: Regions with depth ≤ 1km, e.g., coastal & inland waters

VIIRS science quality OC data are processed using the MSL12!

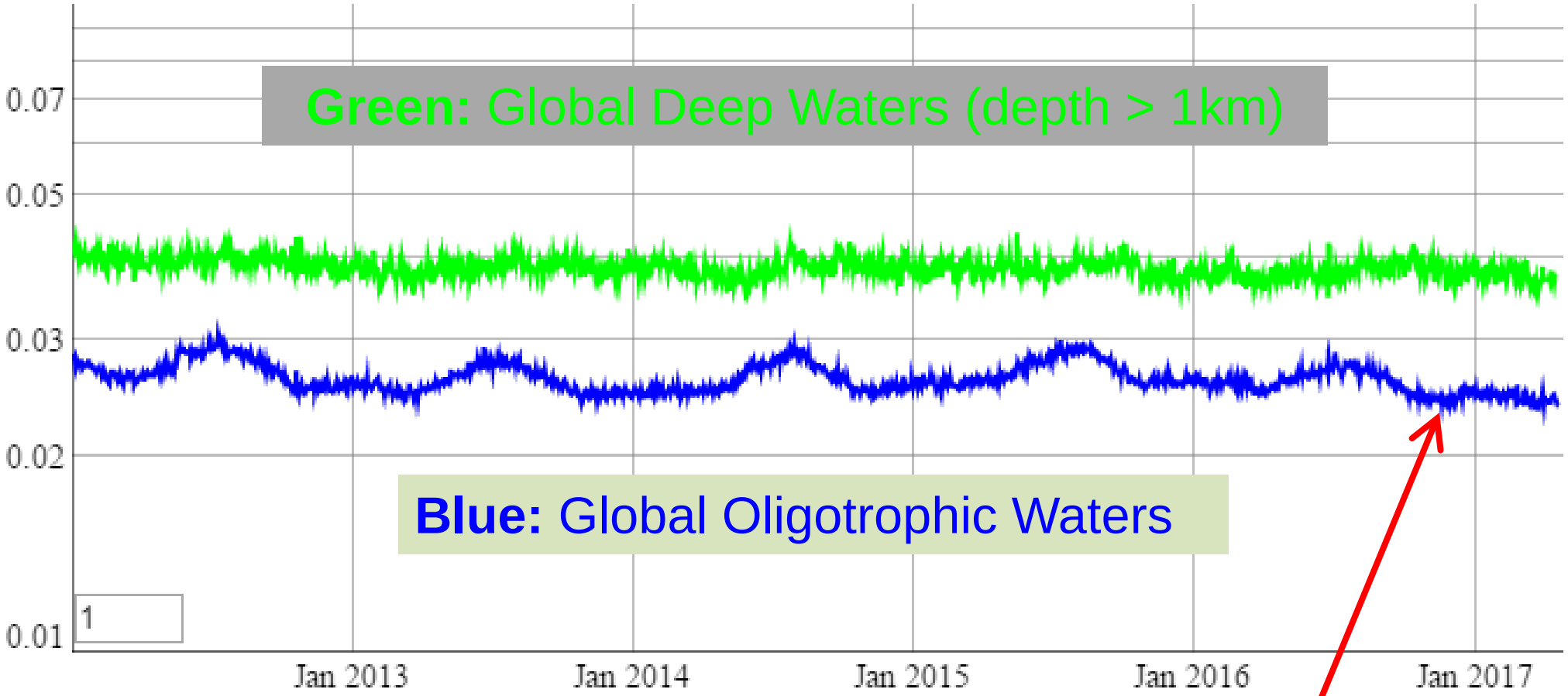
VIIRS-derived Daily Chl-a



Slightly Chl-a drop over oligotrophic waters

VIIRS science quality OC data are processed using the MSL12!

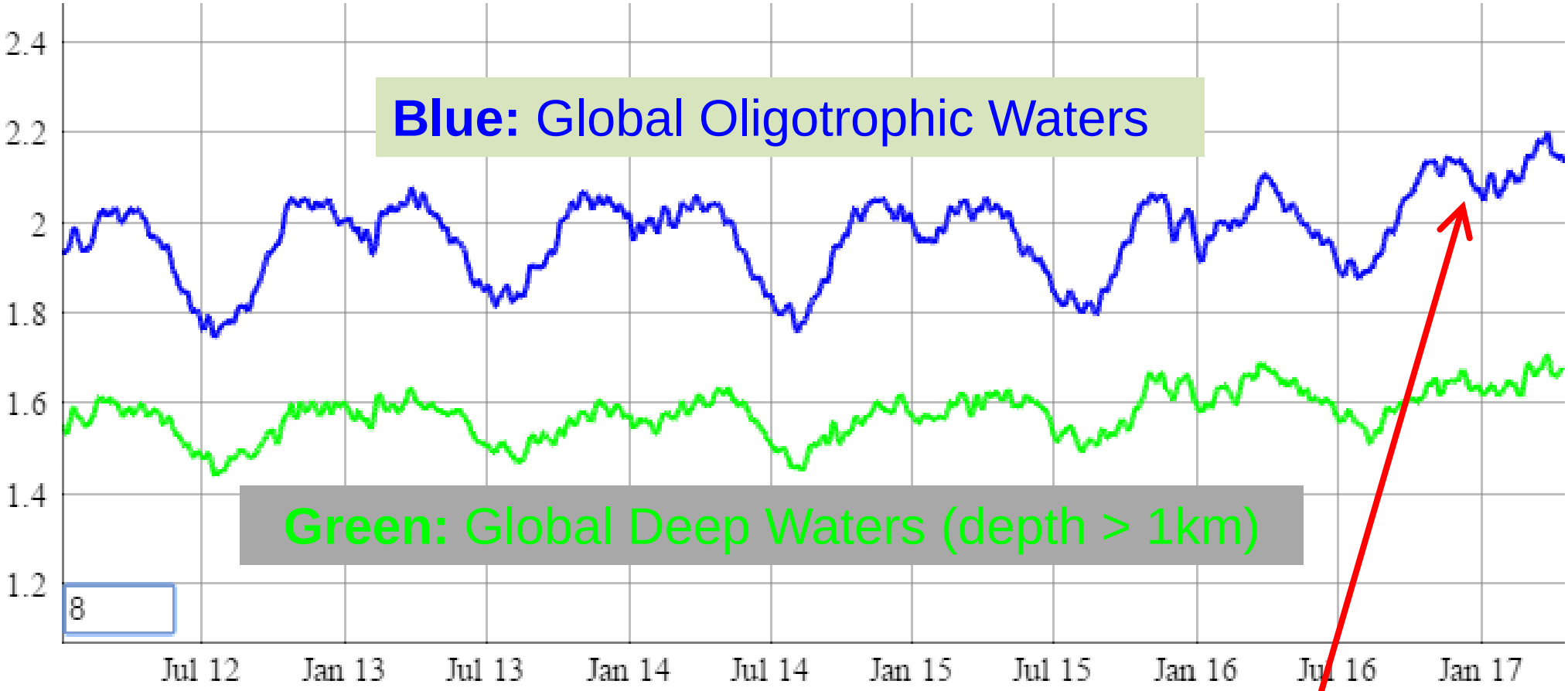
VIIRS-derived Daily $K_d(490)$



Slightly value drop over oligotrophic waters

VIIRS science quality OC data are processed using the MSL12!

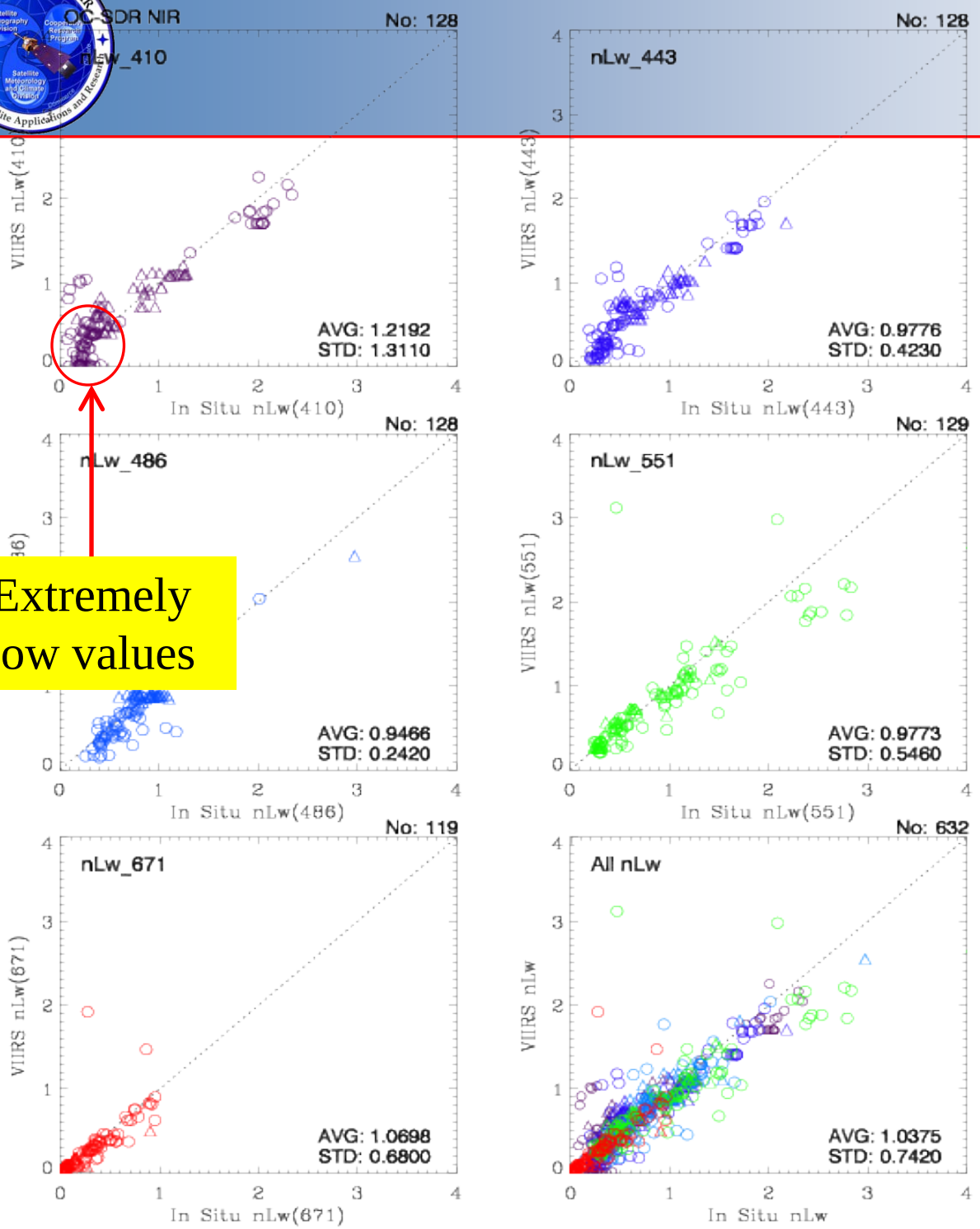
VIIRS-derived 8-day $nL_w(443)$



Water getting **Bluer** recently?

VIIRS science quality OC data are processed using the MSL12!

Validation Effort



Extremely low values

VIIRS vs. In Situ Data

In Situ Data Sources:

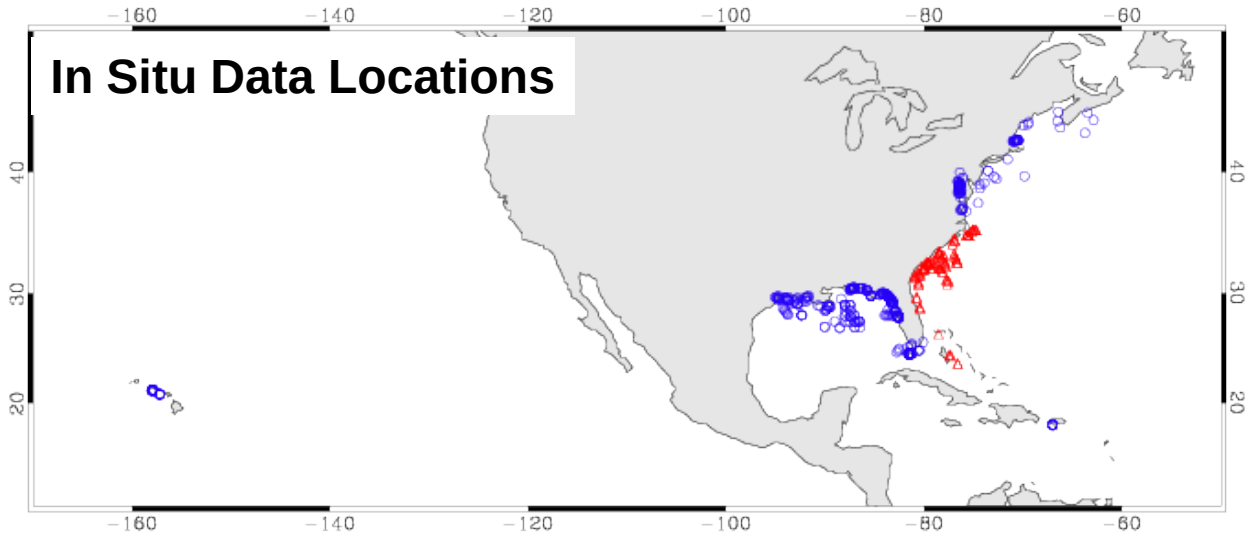
R. Arnone (U. South Miss.)
C. Davis (Oregon State U.)
C. Hu (U. South Florida)
Z. Lee (U. Mass. Boston)
M. Ondrusek (NOAA/STAR)
G. Zibordi (JRC)

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

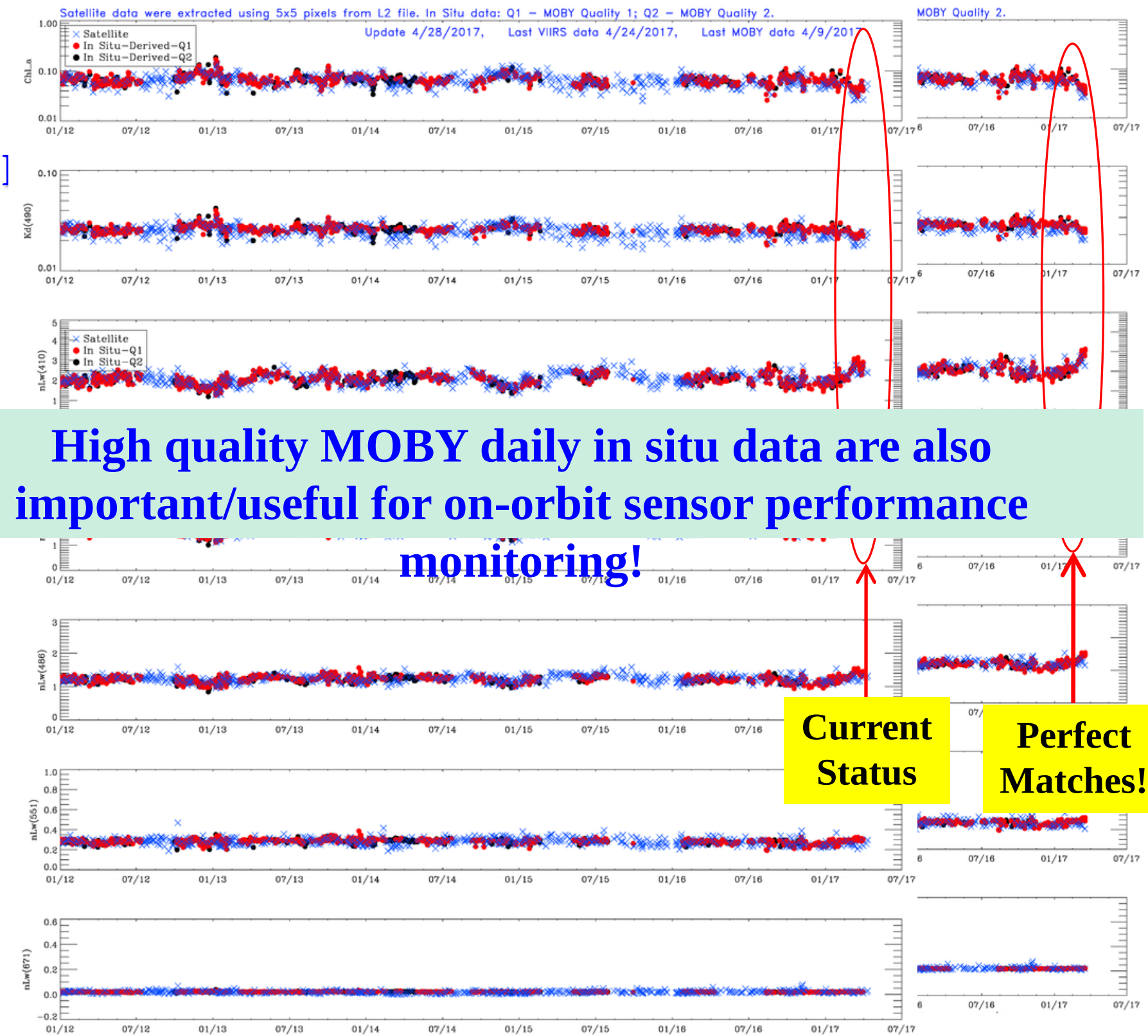
Very significant amount of work!!

Statistics of VIIRS vs. In Situ Data

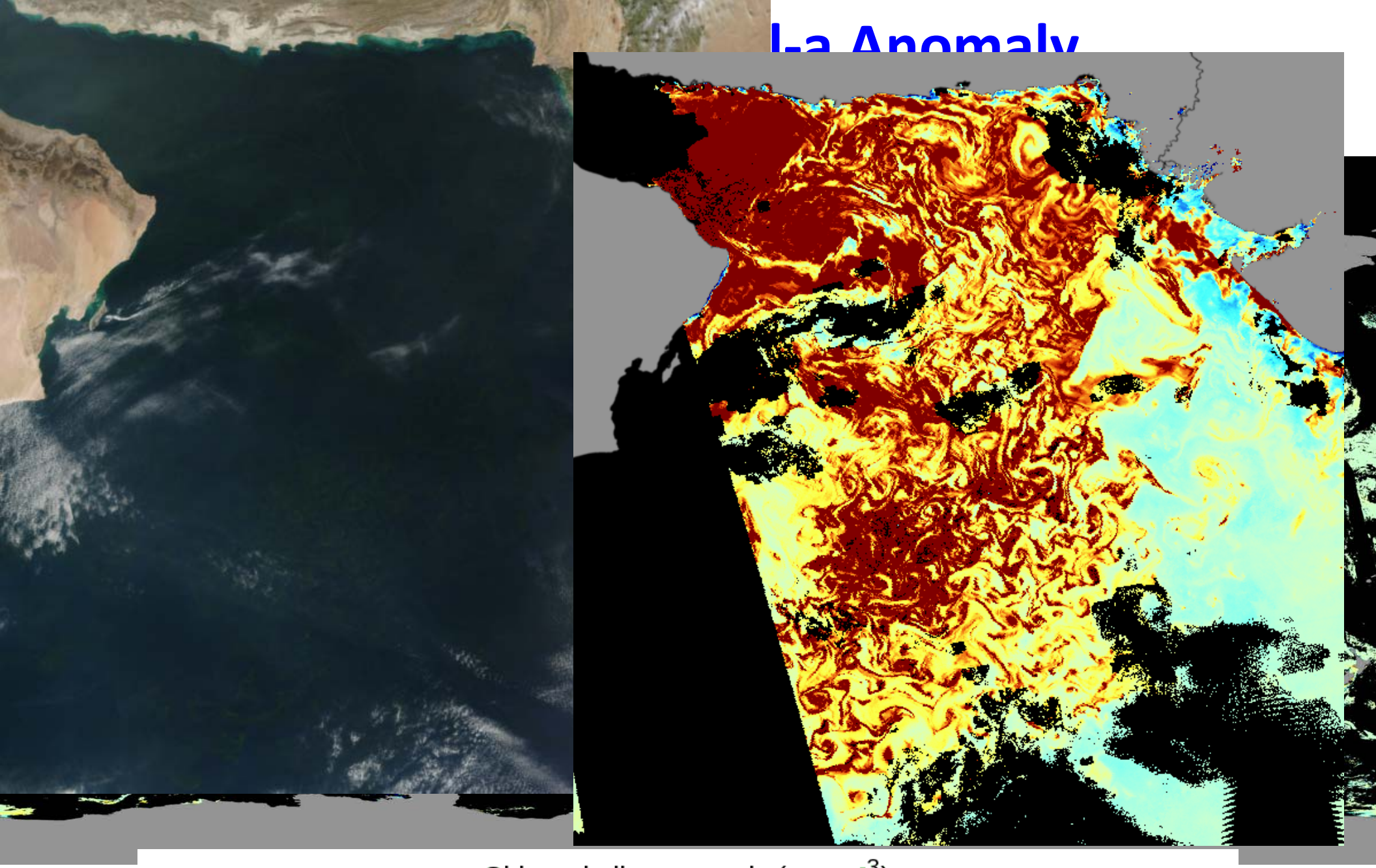
	OC-SDR NIR (Gain in 2017-03-27)							
	RATIO (VIIRS/In Situ)				DIFFERENCE (VIIRS-In Situ)			
	AVG	MED	STD	No	AVG	MED	STD	%Diff
$nL_w(410)$	1.2192	0.9658	1.311	128	0.0041	-0.0307	0.241	0.600
$nL_w(443)$	0.9776	0.9202	0.423	128	-0.0330	-0.0697	0.191	-4.310
$nL_w(486)$	0.9466	0.9298	0.242	128	-0.0471	-0.0520	0.192	-5.320
$nL_w(551)$	0.9773	0.9316	0.546	129	-0.0783	-0.0415	0.349	-8.830
$nL_w(671)$	1.0698	0.9768	0.680	119	-0.0102	0.0013	0.181	-4.120
All	1.0375	0.9383	0.742	632	-0.0333	-0.0290	0.241	-4.750



- Red: The three dedicated Cal/Val cruises
- Blue: Various in situ measurement opportunities


Satellite data were extracted using 5x5 pixels from L2 file. In Situ data: Q1 – MOBY Quality 1; Q2 – MOBY Quality 2.
Update 4/28/2017, Last VIIRS data 4/24/2017, Last MOBY data 4/9/2017
MOBY Quality 2.
Satellite
In Situ-Derived-Q1
In Situ-Derived-Q2
Chl_a
Kd(490)
Satellite
In Situ-Q1
In Situ-Q2
nLw(410)
nLw(486)
nLw(551)
nLw(671)
01/12
07/12
01/13
07/13
01/14
07/14
01/15
07/15
01/16
07/16
01/17
07/17
High quality MOBY daily in situ data are also important/useful for on-orbit sensor performance monitoring!
Current Status
Perfect Matches!

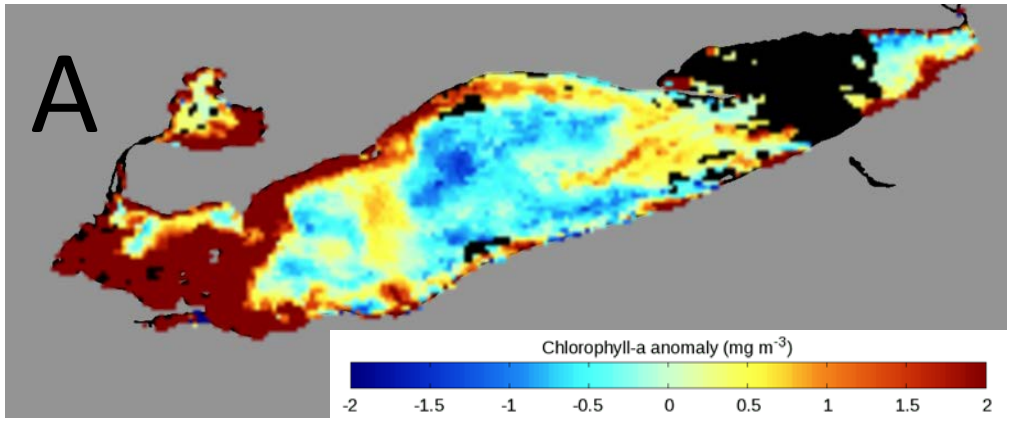
l-a Anomaly



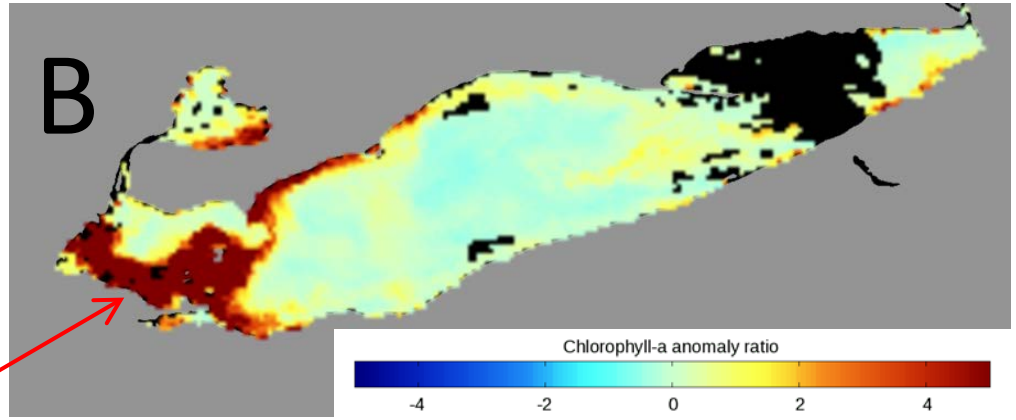
Stumpf, R. P., M. E. Culver, P. A. Tester, M. Tomlinson, G. J. Kirkpatrick, B. A. Pederson, E. Truby, V. Ransibrahmanakul, and M. Soracco, "Monitoring *Karenia brevis* blooms in the Gulf of Mexico using satellite ocean color imagery and other data," *Harmful Algae*, **2**, 147–160, 2003.

Regional Example: Lake Erie
2015-07-28

A: Chlorophyll-a anomaly
B: Chlorophyll-a anomaly ratio
C: true color



For coastal/inland waters with high Chlorophyll-a, the **anomaly ratio** (B) may be a better indicator



Shape matches perfectly!

Please Visit Our 10 Posters from NOAA/STAR

(Calibrations, Algorithms, Validations, Applications, In Situ Data)

- Mike Chu, **Junqiang Sun**, and Menghua Wang, **Radiometric evaluation of the SNPP VIIRS reflective solar band sensor data records via inter-sensor comparison with Aqua MODIS**.
- **Veronica P. Lance**, Michael Ondrusek, Heng Gu, Menghua Wang and NOAA VIIRS Cruise, VIIRS Cal/Val, MOBY and Aeronet-OC Team Members, **NOAA in situ validation activities for satellite ocean color products and related ocean science research**.
- **Xiaoming Liu** and Menghua Wang, **Reconstruction of Missing Data in the VIIRS Global Ocean Color Images Using the DINEOF Method**.
- **Karlis Mikelsons** and Menghua Wang, **OCView - interactive online visualization and monitoring tool for satellite ocean color data imagery**.
- **Wei Shi** and Menghua Wang, **A New Algorithm Deriving VIIRS Particle Backscattering Coefficient bbp(λ) Products in the Global Highly Turbid Waters**.
- **SeungHyun Son** and Menghua Wang, **Evaluation of VIIRS Ocean Color Products in Open Ocean and Coastal/Inland Waters**.
- **SeungHyun Son**, Menghua Wang, and Lide Jiang, **Comparison of GOCI and VIIRS Ocean Color Products in the Western Pacific Region**.
- **Junqiang Sun** and Menghua Wang, **SNPP VIIRS Reflective solar bands calibration improvements and updates**.
- **Menghua Wang**, Lide Jiang, Xiaoming Liu, SeungHyun Son, Junqiang Sun, Karlis Mikelsons, Wei Shi, Liqin Tan, Xiaolong Wang, Mike Chu, and Veronica Lance, **Progress Updates of VIIRS Ocean Color Products**.
- **Guangming Zheng** and Paul M. DiGiacomo, **Optical characterization of suspended particles along two estuarine transects using VIIRS data**.