Validated Stage Science Maturity Review for VIIRS Ocean Color Products

Menghua Wang
& VIIRS Ocean Color EDR Team

Inputs & contributions from
the VIIRS Ocean Color Cal/Val Team and Users

March 27, 2015

Outline

- VIIRS Ocean Color Team Members
- Product Requirements
- Description of ocean color products
- Evaluation of algorithm performance to specification requirements
  - Ocean color algorithms, improvements, and updates
  - VIIRS ocean color product evaluation
  - Error Budget
  - Quality flags
- Documentation
- Users & User Feedback
- Path Forward
- Conclusion

VIIRS Ocean Color EDR & Cal/Val Teams Members

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, P. Naik, J. Sun, K. Mikelsons, 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, 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	Coordination Look Up Tables – SDR-EDR impacts, vicarious calibration Satellite matchup tool (SAVANT) – Golden Regions cruise participation WAVE_CIS (AERONET site)
	Carol Johnson	NIST	JPSS/NJO	Traceability, AERONET Uncertainty
	Curt Davis, Nicholas Tufillaro	OSU	JPSS/NJO	Ocean color validation, Cruise data matchup West Coast
	Burt Jones, Matthew Ragan	USC	JPSS/NJO	Eureka (AERONET Site)
	Sam Ahmed, Alex Gilerson	CUNY	JPSS/NJO	LISCO (AERONET site) Cruise data and matchup
	Chuanmin Hu	USF	JPSS/NJO	NOAA data continuity
	Ken Voss & **MOBY** team	RSMAS –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** (C. Cao, F. DeLuccia, X. Xiong), DPA/DPE (R. Williamson, Neal Baker), Raytheon, NOAA OC Working Group, NOAA various line-office reps, NASA OBPG (K. Turpie, et al.), NOAA OCPOP, 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 on Suomi NPP

has Ocean and SWIR spectral bands similar to **MODIS**

VIIRS†		MODIS		SeaWiFS
Ocean Bands (nm)	Other Bands (nm)	Ocean Bands (nm)	Other Bands (nm)	Ocean Band (nm)
410 (M1)	640 (I1)	412	645	412
443 (M2)	865 (I2)	443	859	443
486 (M3)	1610 (I3)	488	469	490
—		531	555	510
551 (M4)	*SWIR Bands*	551	*SWIR Bands*	555
671 (M5)	1238 (M8)	667	1240	670
745 (M6)	1610 (M10)	748	1640	765
862 (M7)	2250 (M11)	869	2130	865

†VIIRS nominal center wavelength

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

JPSS Environmental Requirements Document

JERD-2128 18, 19, 30, 75	Ocean Color/Chlorophyll under clear conditions	The algorithm shall produce an OC/C product during clear conditions.
JERD-2129 18, 19, 30, 75	Ocean Color/Chlorophyll during daytime	The algorithm shall produce an OC/C product during daytime conditions.
JERD-2130 18, 19, 30, 75	Ocean Color/Chlorophyll horizontal cell size	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 From SDR	Ocean Color/Chlorophyll mapping uncertainty	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 38-54, 60-70	Ocean Color/Chlorophyll measurement range	The algorithm shall produce an OC/C product that has a measurement range of 0.1 – 50 W/m2/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/m3 for chlorophyll.
JERD-2133 38-54, 60-70	Ocean Color/Chlorophyll measurement precision	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/m3 30% for chlorophyll at 1.0 mg/m3 < Ch1 < 10 mg/m3, and 50% for chlorophyll at Ch1 > 10 mg/m3.
JERD-2134 38-54, 60-70	Ocean Color/Chlorophyll measurement accuracy	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/m3 30% operational (25% science quality) for chlorophyll at 1.0 mg/m3 < Ch1 < 10 mg/m3, and 40% operational (30% science quality) for chlorophyll at Ch1 > 10 mg/m3.
JERD-2135 38-54, 60-70	Ocean Color/Chlorophyll errors correlated as observed in heritage data	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.

JPSS Data Products Maturity Definition

JPSS/GOES-R Data Product Validation Maturity Stages – COMMON DEFINITIONS (Nominal Mission)

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 operational use (user decision) and in scientific publications.

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.

History of MSL12 in JPSS

MSL12 is now an official VIIRS ocean color data processing system:

- Multi-Sensor Level-1 to Level-2 (MSL12) was originally developed in 1998-2000 and used to process satellite ocean color data for SeaWiFS, MODIS, MOS, OCTS, POLDER, GOCI, etc.
- MSL12 has been routinely running since the beginning of VIIRS mission and as a validation for IDPS ocean color products.
- January 7-8, 2014, the **provisional** status request for IDPS ocean color EDR was made.
- In April 2014, with CoastWatch evaluation results and feedback from users, JPSS decided to use MSL12 for VIIRS ocean color data process.
- April 30, 2014, JPSS Ocean Color product Analysis of Alternatives (AoA) kick off meeting minutes distributed and the AoA process started.
- May 2014, VIIRS OC team delivered MSL12 package to CoastWatch and it has been running there since then.
- October 28, 2014, JPSS decided that "**Okeanos** serve as a near-term stopgap solution to get the NOAA users this critical product in the near term."
- OC team agreed to deliver an improved MSL12 package (e.g., coastal water processing) for VIIRS ocean color data processing in April 2015.

Summary of VIIRS Ocean Color EDR Products

- **Inputs**:
  - VIIRS M1-M7 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
  - Chlorophyll-a (Chl-a) concentration
  - Diffuse attenuation coefficient for the downwelling spectral irradiance at the wavelength of 490 nm, $K_d(490)$ (New)
  - Diffuse attenuation coefficient of the downwelling photosynthetically available radiation (PAR), $K_d(\mathrm{PAR})$ (New)
  - Level-2 quality flags
- **Experimental Products:**
  - 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)
  - Chlorophyll-a from ocean color index (OCI) method (Hu et al., 2012)
  - Others from users requests

➢ 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).
  - Level-2 to global Level-3 (routine daily, 8-day, monthly, and climatology data/images).
- Support of in situ data collections for VIIRS Cal/Val activities, e.g., **MOBY**, **AERONET-OC** sites, **NOAA dedicated cruise**, etc.
- On-orbit instrument calibration:
  - J. Sun and M. Wang, "Visible Infrared Imaging Radiometer Suite solar diffuser calibration and its challenges using solar diffuser stability monitor," *Appl. Opt.,* **53***,* 8571-8584, 2014.
  - J. Sun and M. Wang, "On-orbit characterization of the VIIRS solar diffuser and solar diffuser screen," *Appl. Opt.*, **54**, 236-252, 2015.
  - J. Sun and M. Wang, "VIIRS Reflective Solar Bands On-Orbit Calibration and Performance: A Three-Year Update," *Proc. SPIE* 9264*, Earth Observing Missions and Sensors: Development, Implementation, and Characterization III,* October 13-16, 2014.
- RDR (Level-0) to SDR (Level-1B) data 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.
  - L. Tan, M. Wang, J. Sun, and L. Jiang, "VIIRS RDR to SDR Data Processing for Ocean Color EDR," *Proc. SPIE* 9261*, Ocean Remote Sensing and Monitoring from Space,* October 13-16, 2014.
- **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.

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.

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

Welcome to VIIRS Ocean Color EDR Team Web Site

STAR Center for Satellite Applications and Research VIIRS Ocean Color EDR Team

The ocean color research team in the Center for Satellite Applications and Research (STAR) of NOAA/NESDIS seeks to develop improved ocean color products from the current and future ocean color satellite sensors including the Sea-viewing Wide Field-of-view Sensor (SeaWiFS), the Moderate Resolution Imaging Spectroradiometer (MODIS) on the both Terra and Aqua, and the Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi National Polar-orbiting Partnership (SNPP) and the Joint Polar Satellite System (JPSS), as well as various satellite sensors from other countries, e.g., the Medium Resolution Imaging Spectrometer (MERIS), Geostationary Ocean Color Imager (GOCI), Ocean Land Colour Instrument (OLCI), Second-Generation Global Imager (SGLI), etc. The ocean color research team is currently focusing on (1) satellite ocean color instrument (e.g., VIIRS, MODIS) characterization and calibration, (2) understanding, evaluation, and refining satellite ocean color data processing system, (3) routine global ocean color data processing from Level-1, Level-2, and Level-3, (4) development and improvement of satellite retrieval algorithms in global open ocean and coastal and inland water regions, (5) in situ data processing, evaluation, and improvement, (6) implementing and transition research algorithms to the NOAA operational data system, and (7) various ocean color data applications in global open ocean and the inland and coastal waters.

Here we show results from VIIRS-SNPP.

Please select the page to visit:

VIIRS EDR Composite Images ← Link to composite image page

Calibration/Validation ← Link to calibration/validation page

Team Publications ← List of the team publications

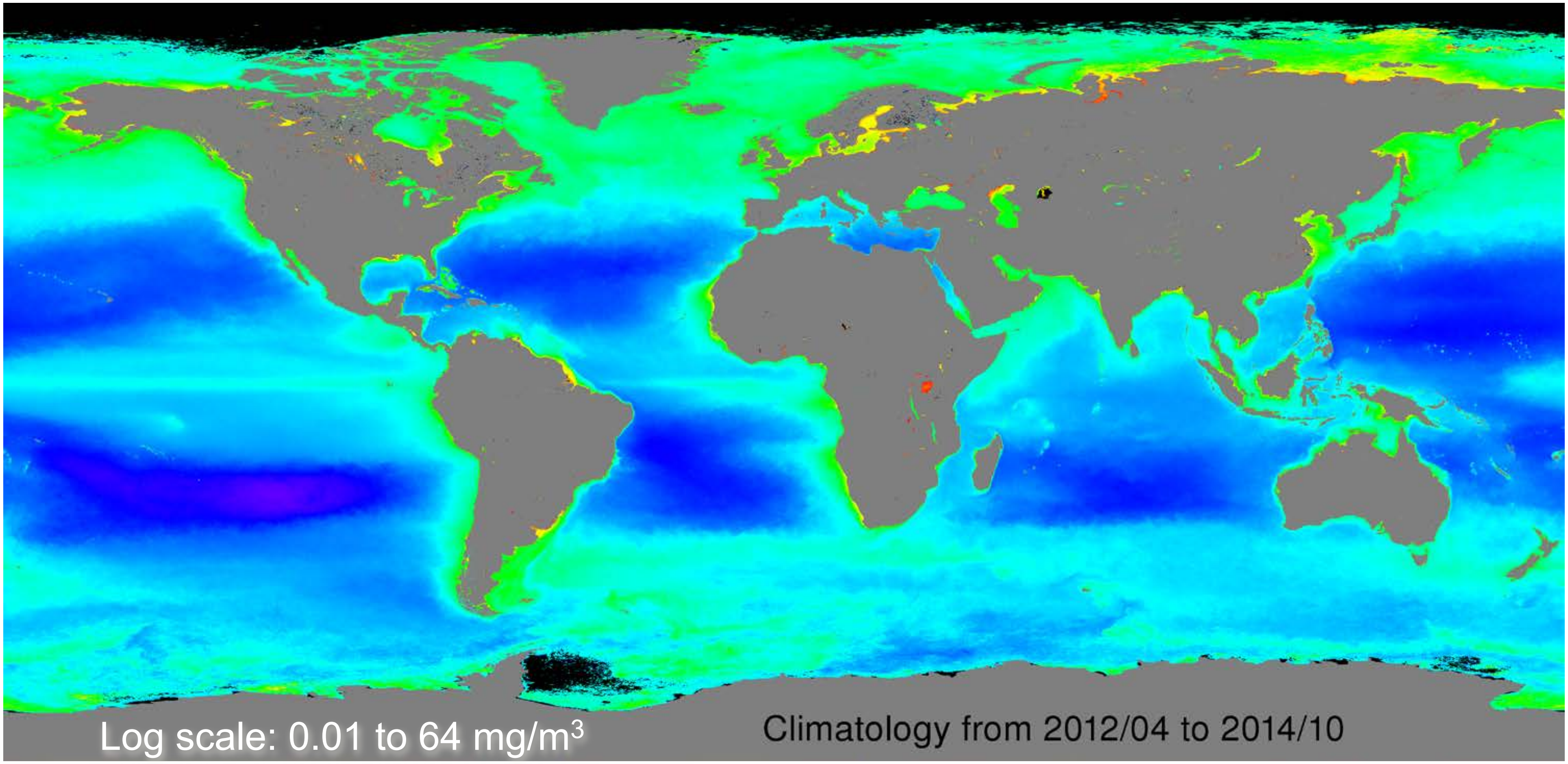
Software Download

Internal Access (password protected)

For detailed information about this site, please refer to the descrption pdf file. ← Website description

Menghua Wang, NOAA/NESDIS/STAR

VIIRS Climatology Chlorophyll-a Image
(April 2012 to October 2014)



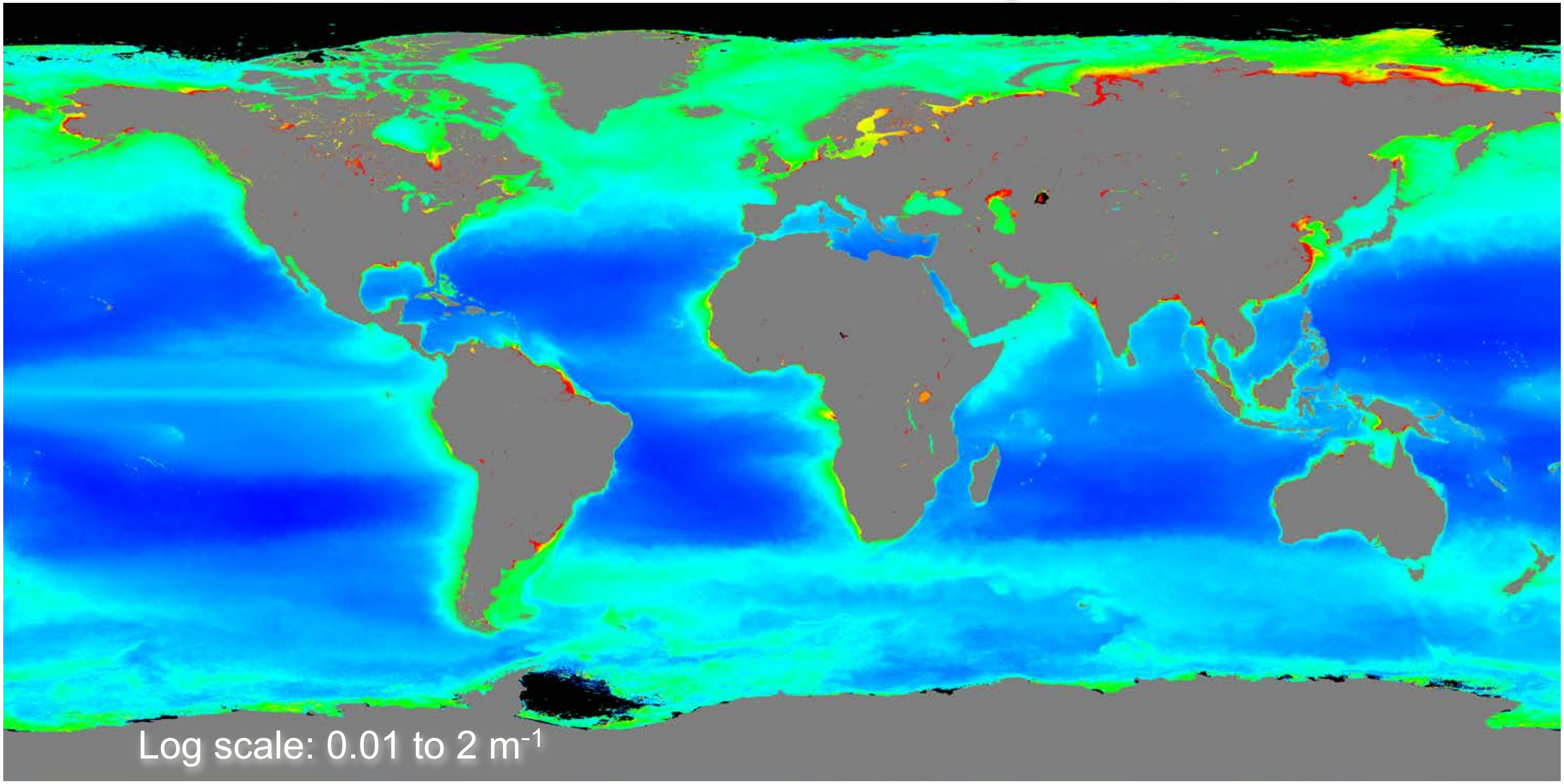
Generated using NOAA-MSL12 for VIIRS ocean color data processing

Wang, M., X. Liu, L. Tan, L. Jiang, S. Son, W. Shi, K. Rausch, and K. Voss, "Impacts of VIIRS SDR performance on ocean color products," *J. Geophys. Res. Atmos.*, **118**, 10,347–10,360, 2013. http://dx.doi.org/10.1002/jgrd.50793

Menghua Wang, NOAA/NESDIS/STAR

VIIRS Climatology $K_d(490)$ Image

(March 2012 to February 2015)

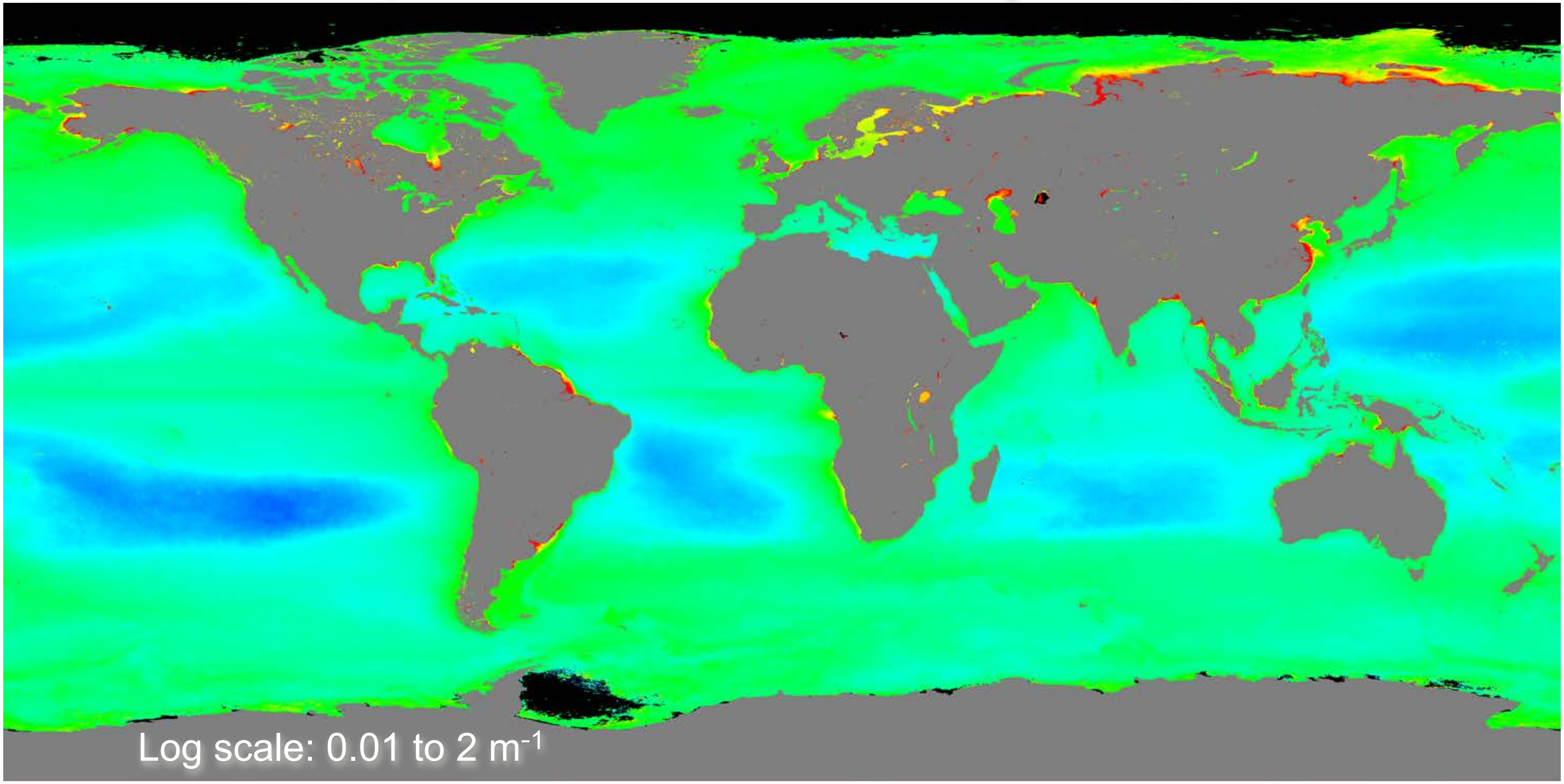


Generated using NOAA-MSL12 for VIIRS ocean color data processing

Menghua Wang, NOAA/NESDIS/STAR

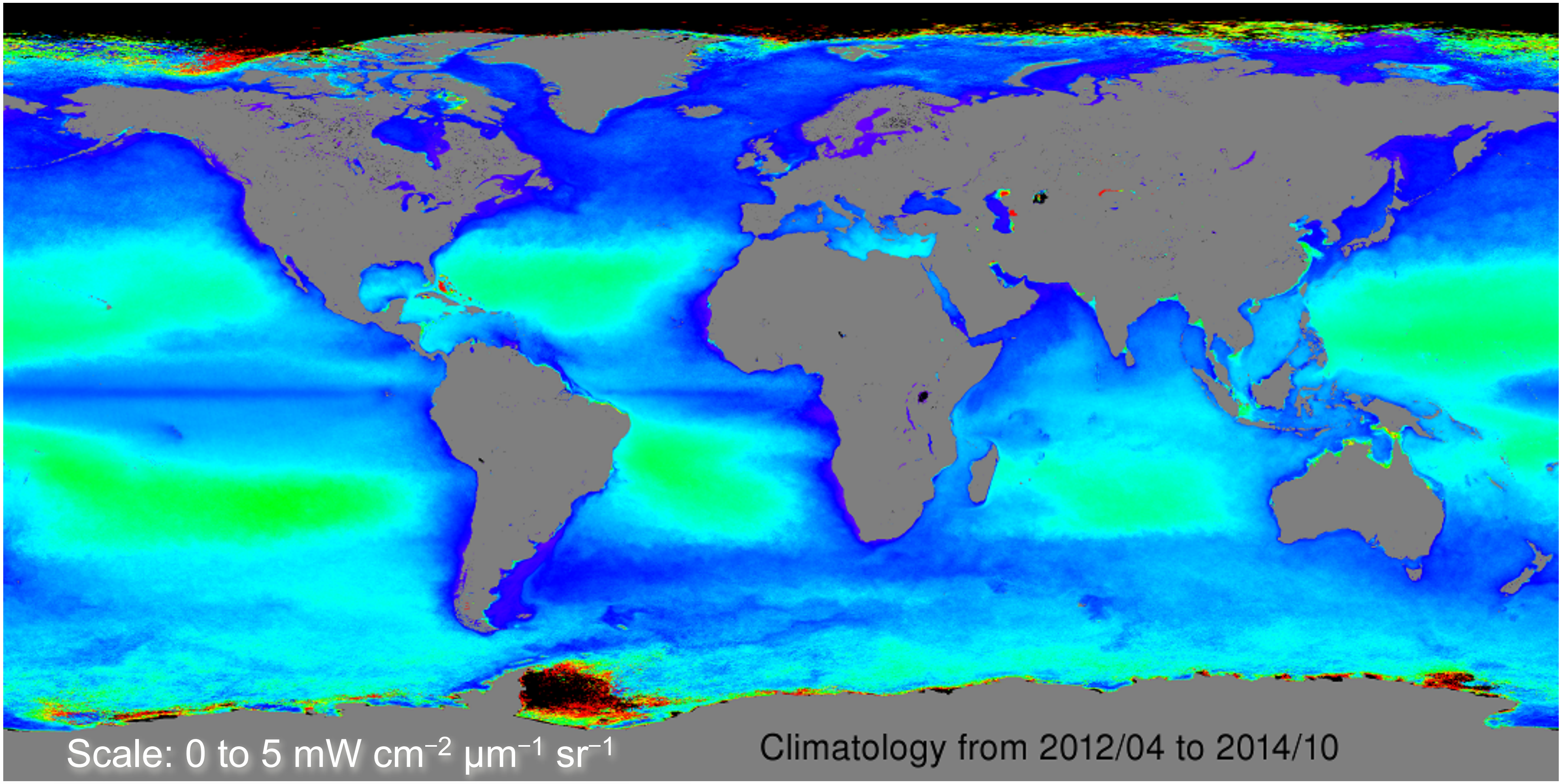
VIIRS Climatology K_d(PAR) Image

(March 2012 to February 2015)



Generated using NOAA-MSL12 for VIIRS ocean color data processing

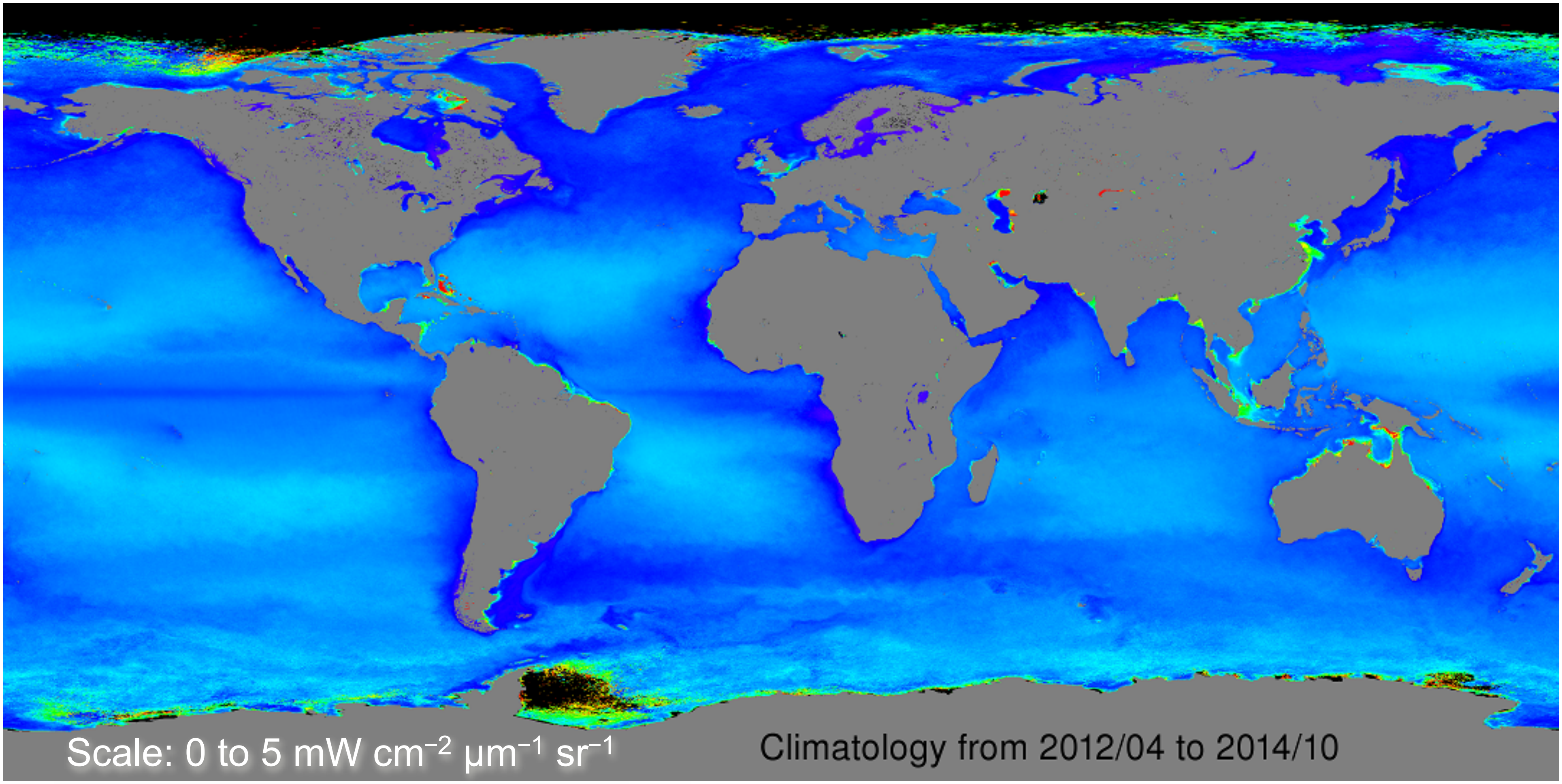
VIIRS Climatology $nL_w(443)$ Image
(April 2012 to October 2014)



Generated using NOAA-MSL12 for VIIRS ocean color data processing

VIIRS Climatology $nL_w(486)$ Image

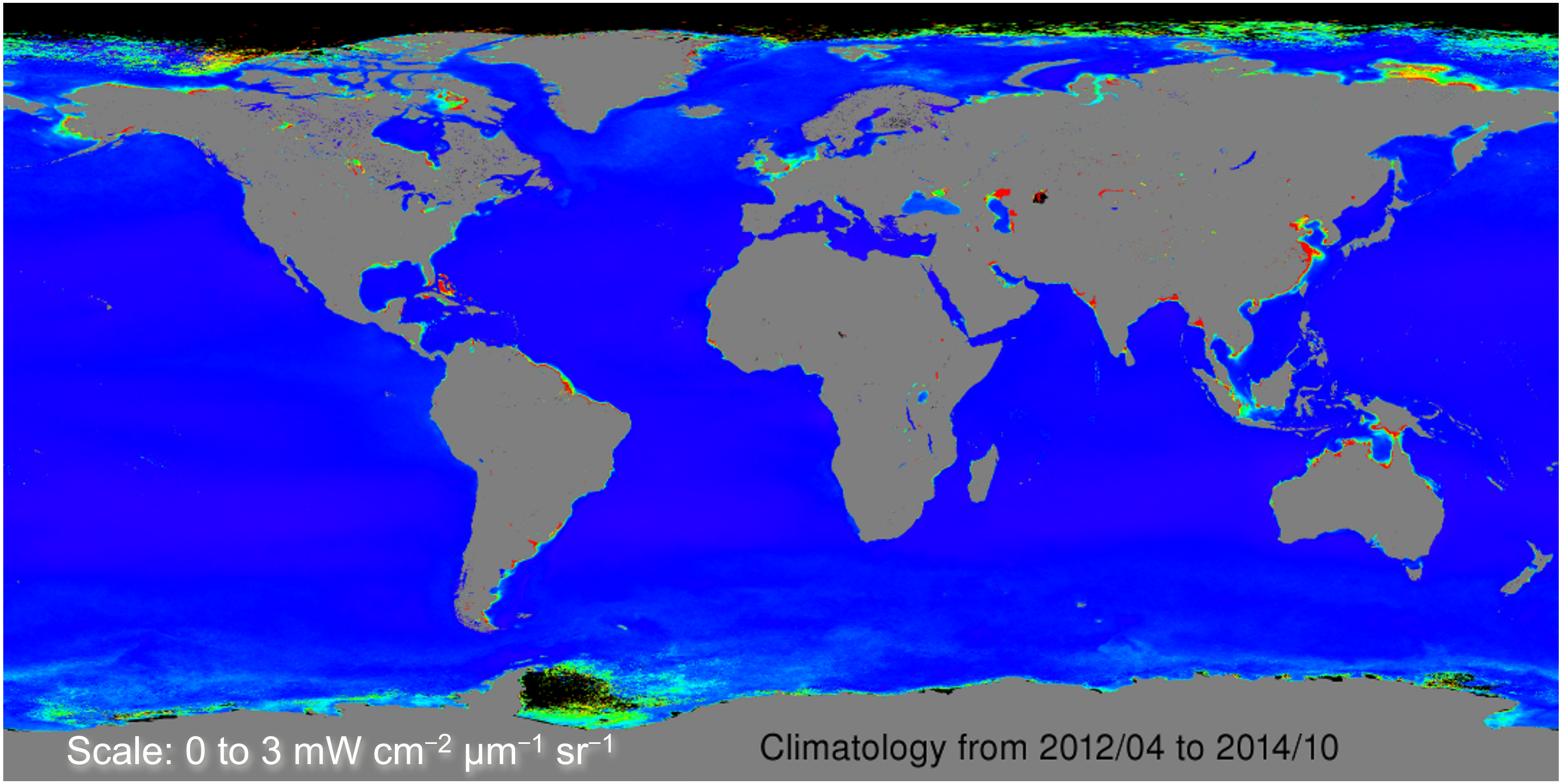
(April 2012 to October 2014)



Generated using NOAA-MSL12 for VIIRS ocean color data processing

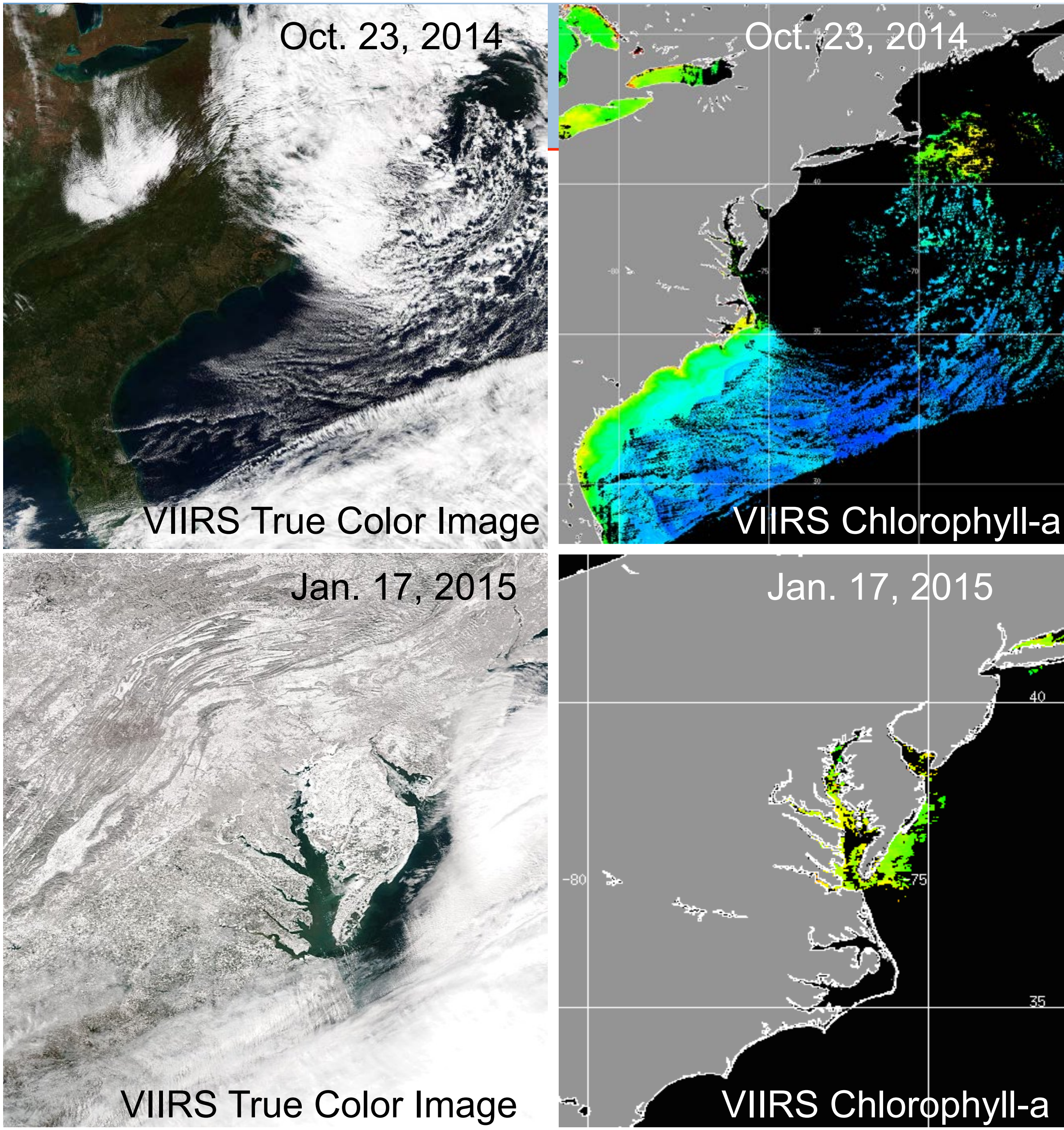
VIIRS Climatology $nL_w(551)$ Image

(April 2012 to October 2014)



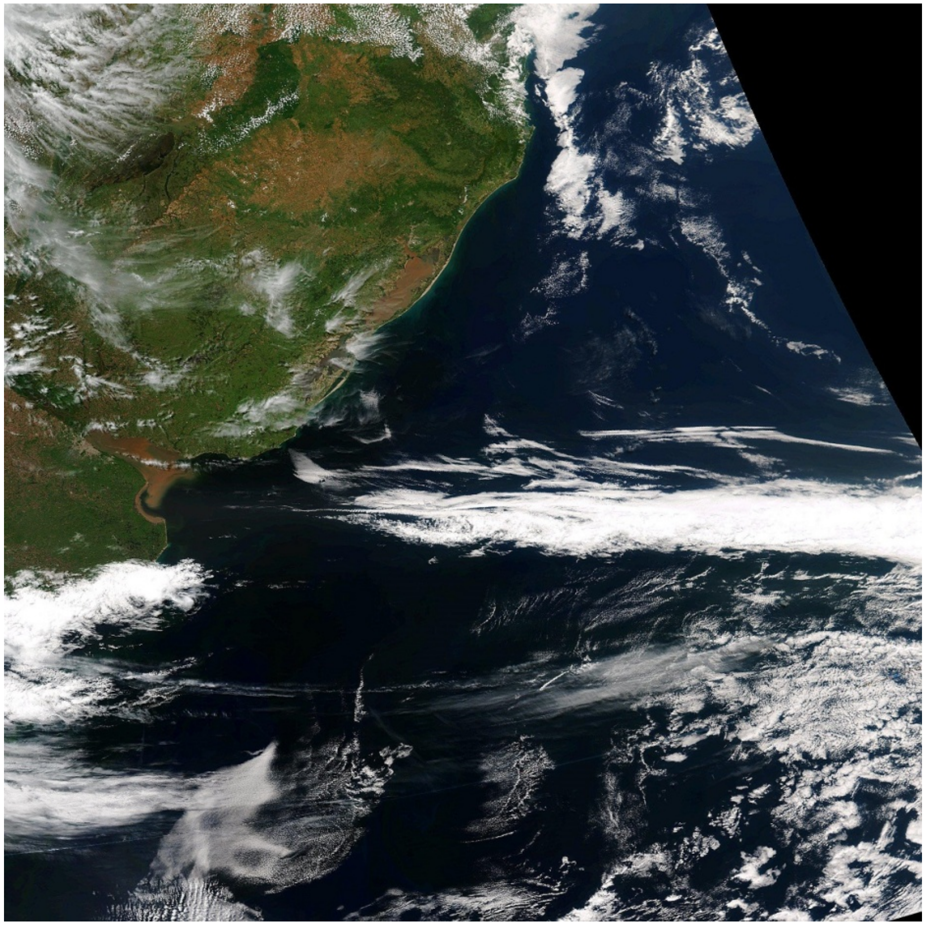
Generated using NOAA-MSL12 for VIIRS ocean color data processing

Data Monitoring:
US East Coast
(Routine Daily Images for Various Coastal Sites)

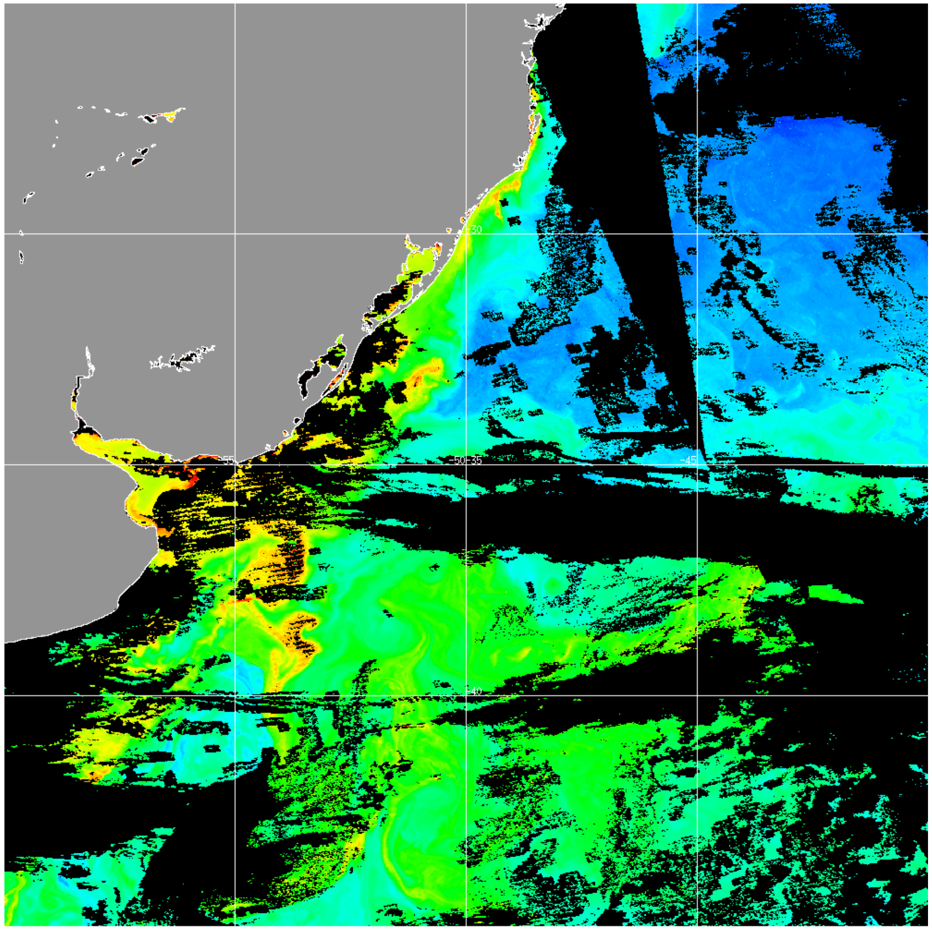


Data Monitoring: La Plata River, Oct. 23, 2014

(Routine Daily Images from Various Coastal Sites)



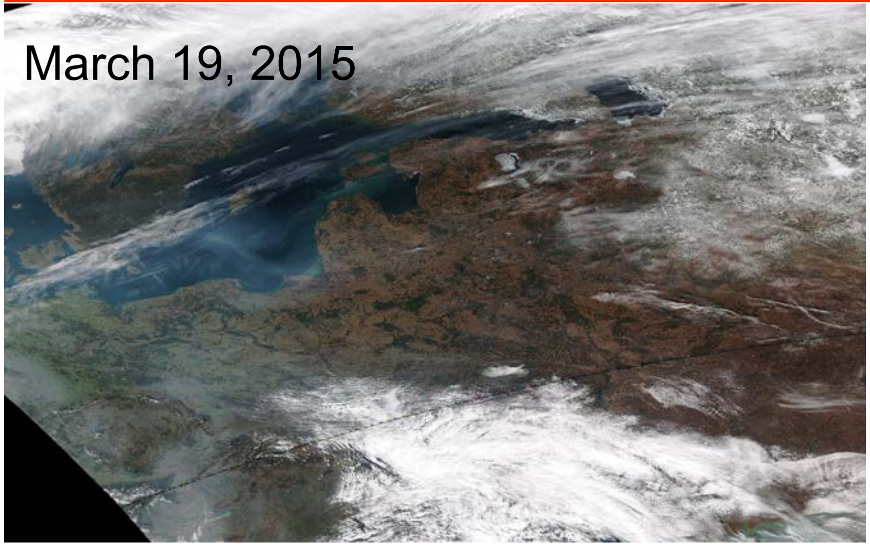
VIIRS True Color Image

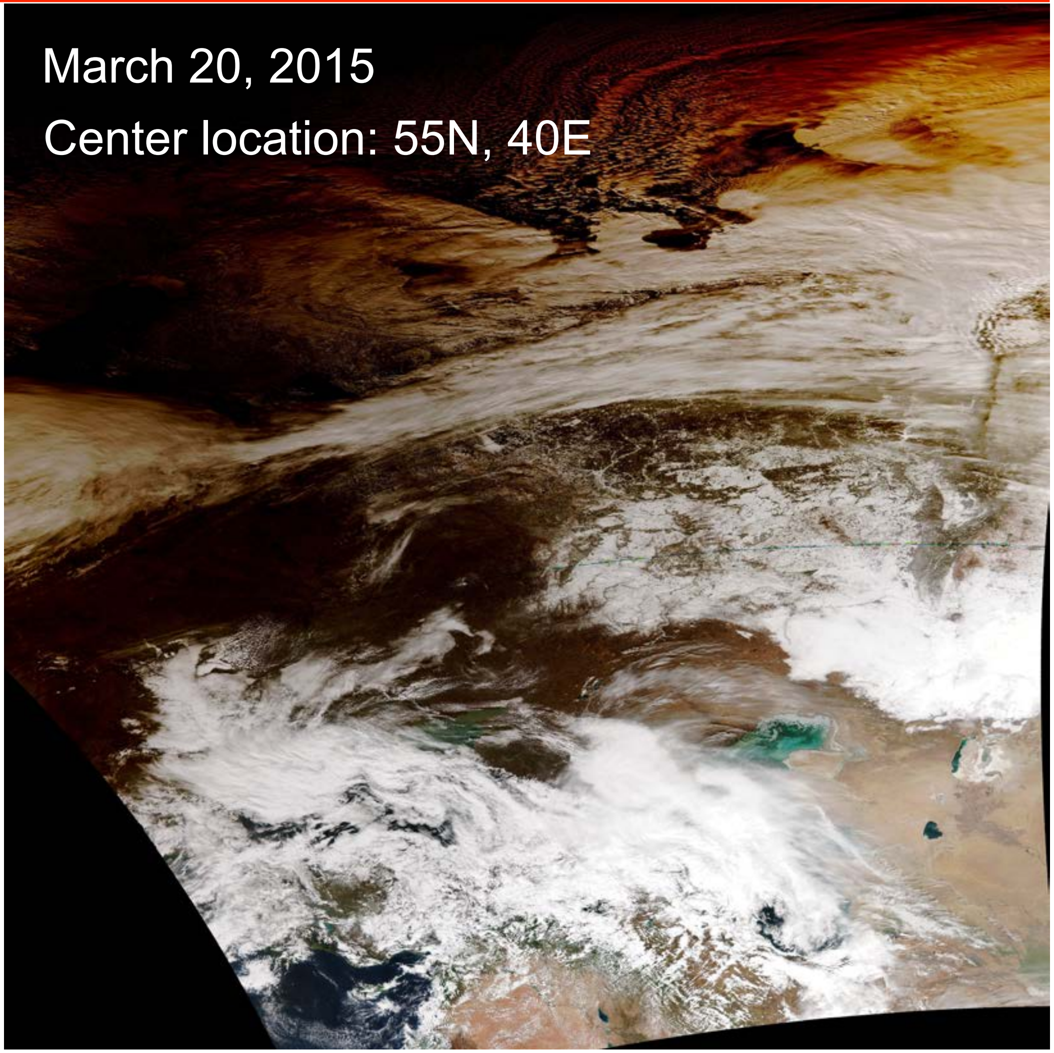


VIIRS Chlorophyll-a

Solar Eclipse Impact on Satellite Remote Sensing

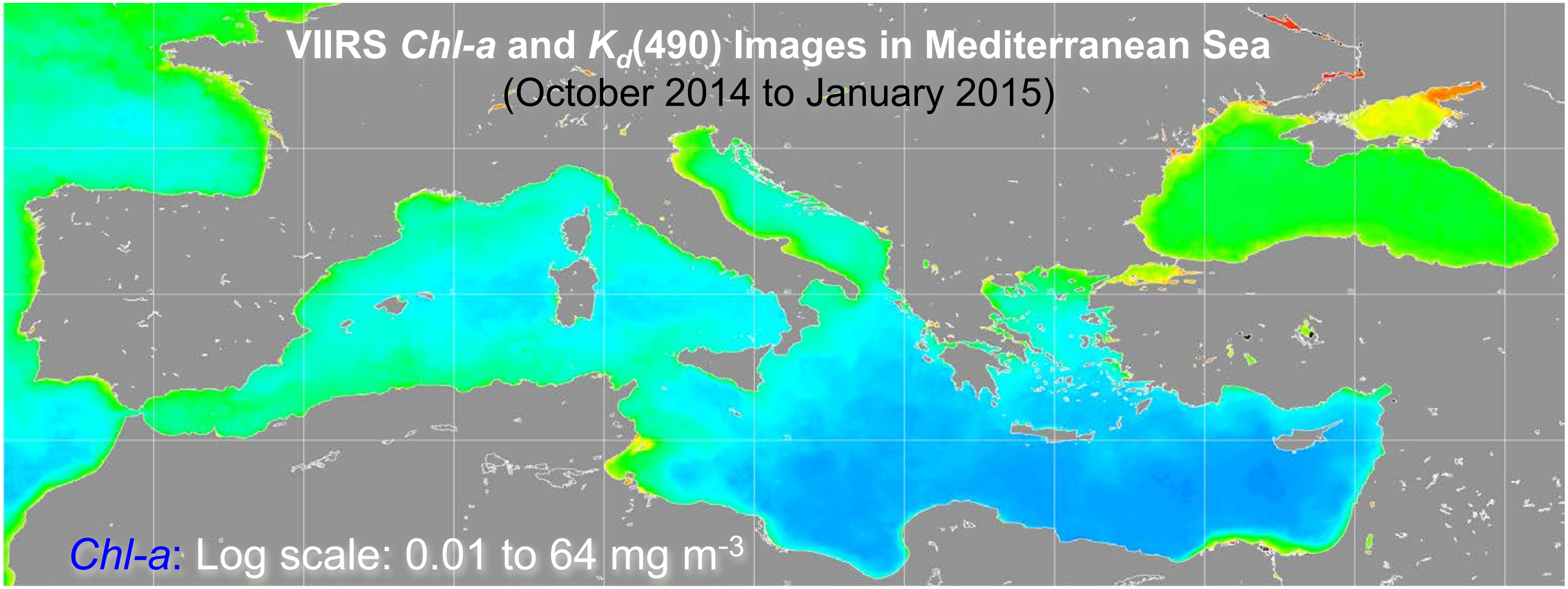
March 20, 2015

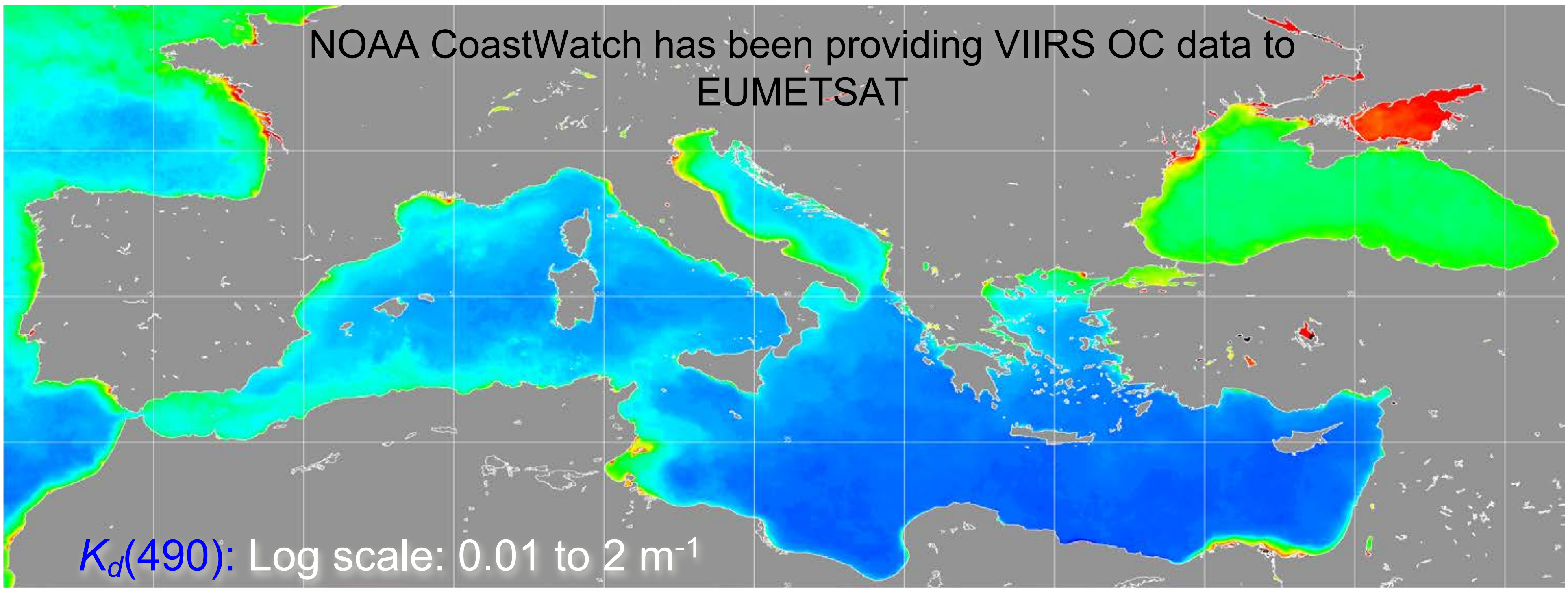




On March 20, 2015, a full solar eclipse occurred in northern hemisphere, with a maximum extent taking place near Faroe islands at 9:47 UTC. A partial eclipse was seen in most of Europe, North Africa and Northwest Asia, from around 7:45 UTC (NW Africa) till 11:50 UTC (Siberia). During this time, the path of eclipse (from west to east) overlapped with the track of **VIIRS** during one of it's orbits.

This picture shows the effect of eclipse on the true color imagery. The data were acquired between 10:03 till 10:15 UTC during an ascending part of the **VIIRS** orbit.


VIIRS *Chl-a* and K_d(490) Images in Mediterranean Sea
(October 2014 to January 2015)
Chl-a: Log scale: 0.01 to 64 mg m^{-3}

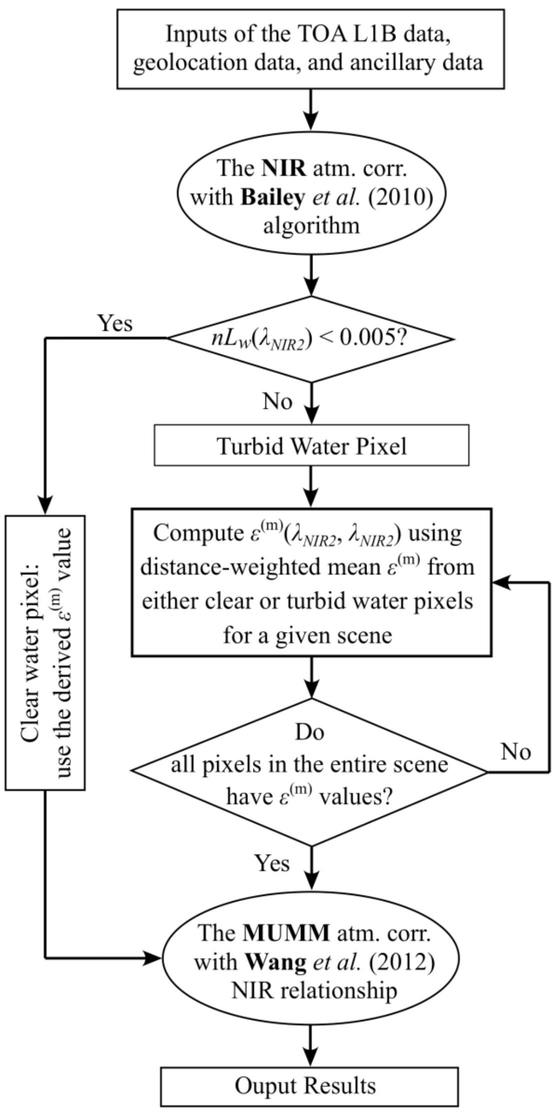

NOAA CoastWatch has been providing VIIRS OC data to EUMETSAT
K_d(490): Log scale: 0.01 to 2 m^{-1}

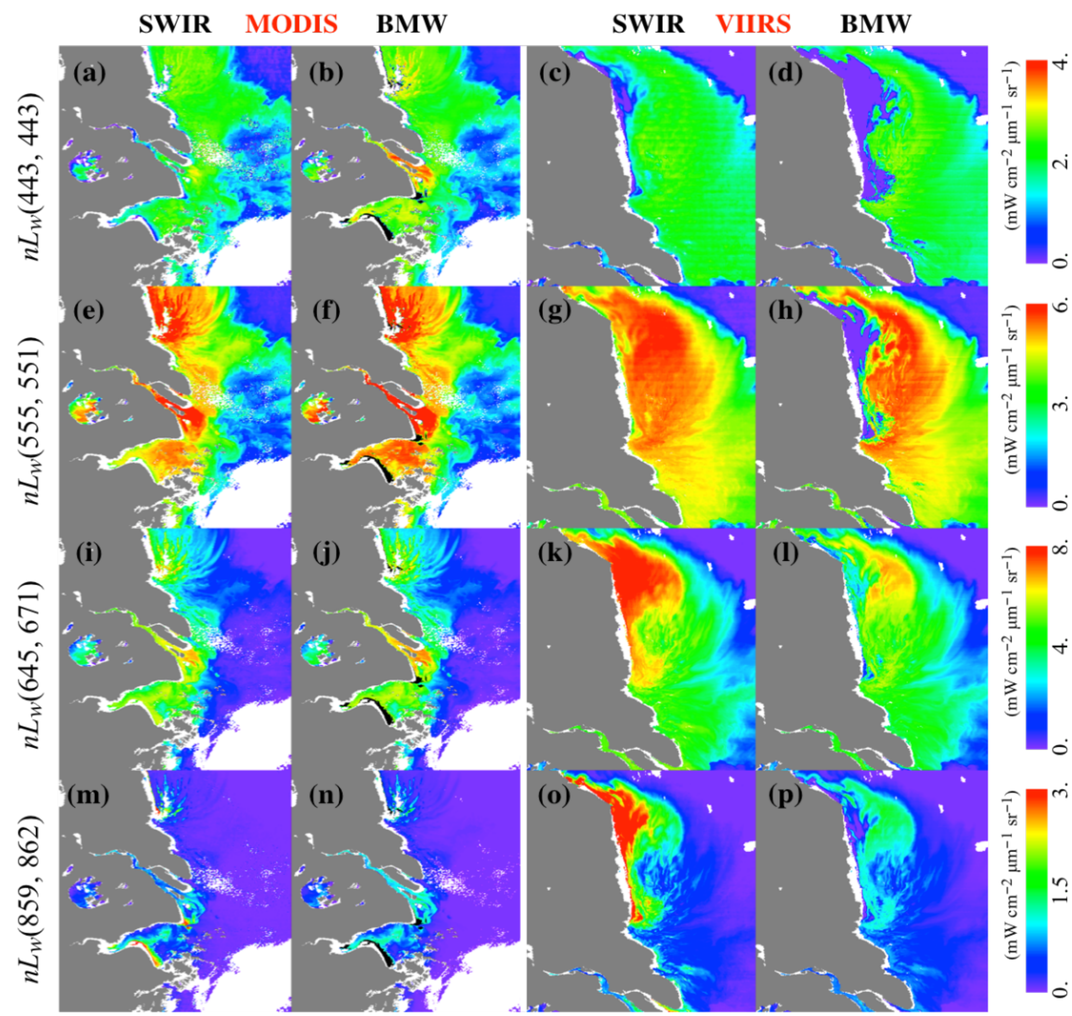
Ocean Color Algorithms, Improvements, and Updates
MSL12 (2015)

- **Algorithms used in the ocean color EDR data processing:**
  - Atmospheric corrections:
    - Gordon & Wang (1994) (and Wang et al. (2005)) for open ocean using the NIR bands
    - Wang (2007) and Wang and Shi (2007) using the SWIR bands
    - The NIR reflectance correction algorithm using **BMW** (Jiang and Wang, 2014) for costal/inland waters (New)
  - Operational chlorophyll-a: OC3V algorithm
  - K_d(490) algorithm: Wang et al. (2009) algorithm (New)
  - K_d(PAR) algorithm: Son and Wang (2015) (New)
  - Destriping algorithm: Mikelsons et al. (2014) (New)
  - Stray light/Cloud shadowing effects: Jiang and Wang (2013) (New)
- **Updates**
  - Polarization correction algorithm (errors are corrected)
- **Experimental Products**
  - IOPs: Quasi-Analytical Algorithm (QAA) (Lee et al., 2002)
  - PAR: Frouin et al. (2003)
  - Chlorophyll-a from OCI method: Hu et al. (2012)

BMW (*Bailey* (2010), *MUMM* (2000), and *Wang* (2012)): A new NIR ocean reflectance correction algorithm

The BMW Algorithm for Ocean Color Data Processing

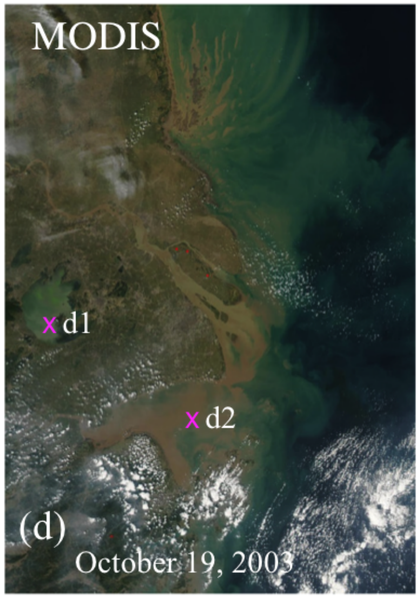


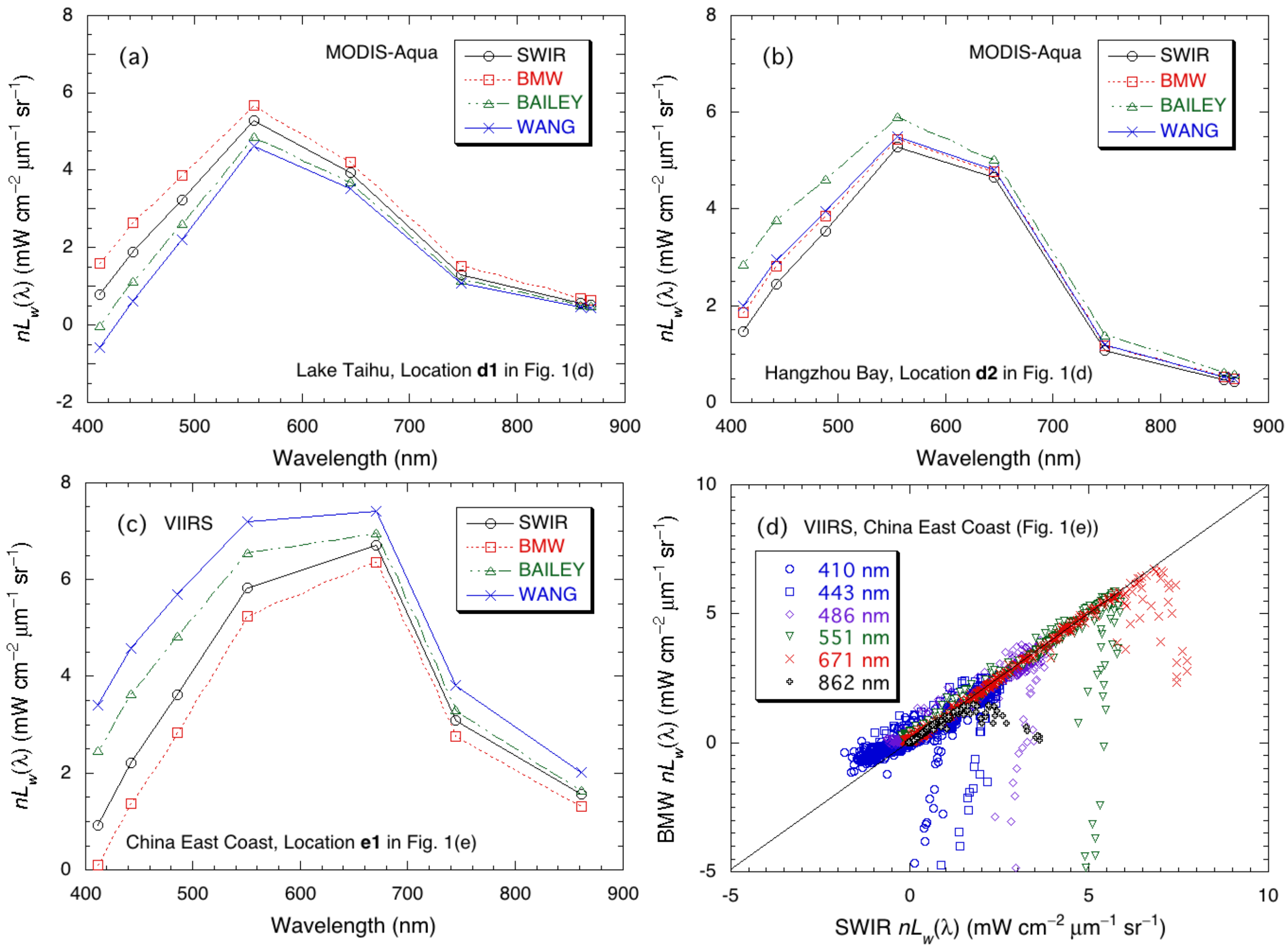


Comparisons of MODIS and VIIRS-derived $nL_w(\lambda)$ images at four selected bands.

Jiang, L. and M. Wang, "Improved near-infrared ocean reflectance correction algorithm for satellite ocean color data processing," *Opt. Express*, **22**, 21,657–21,678, 2014. http://dx.doi.org/10.1364/OE.22.021657

Compare **BMW** with Other Algorithms
(Implemented in MSL12)



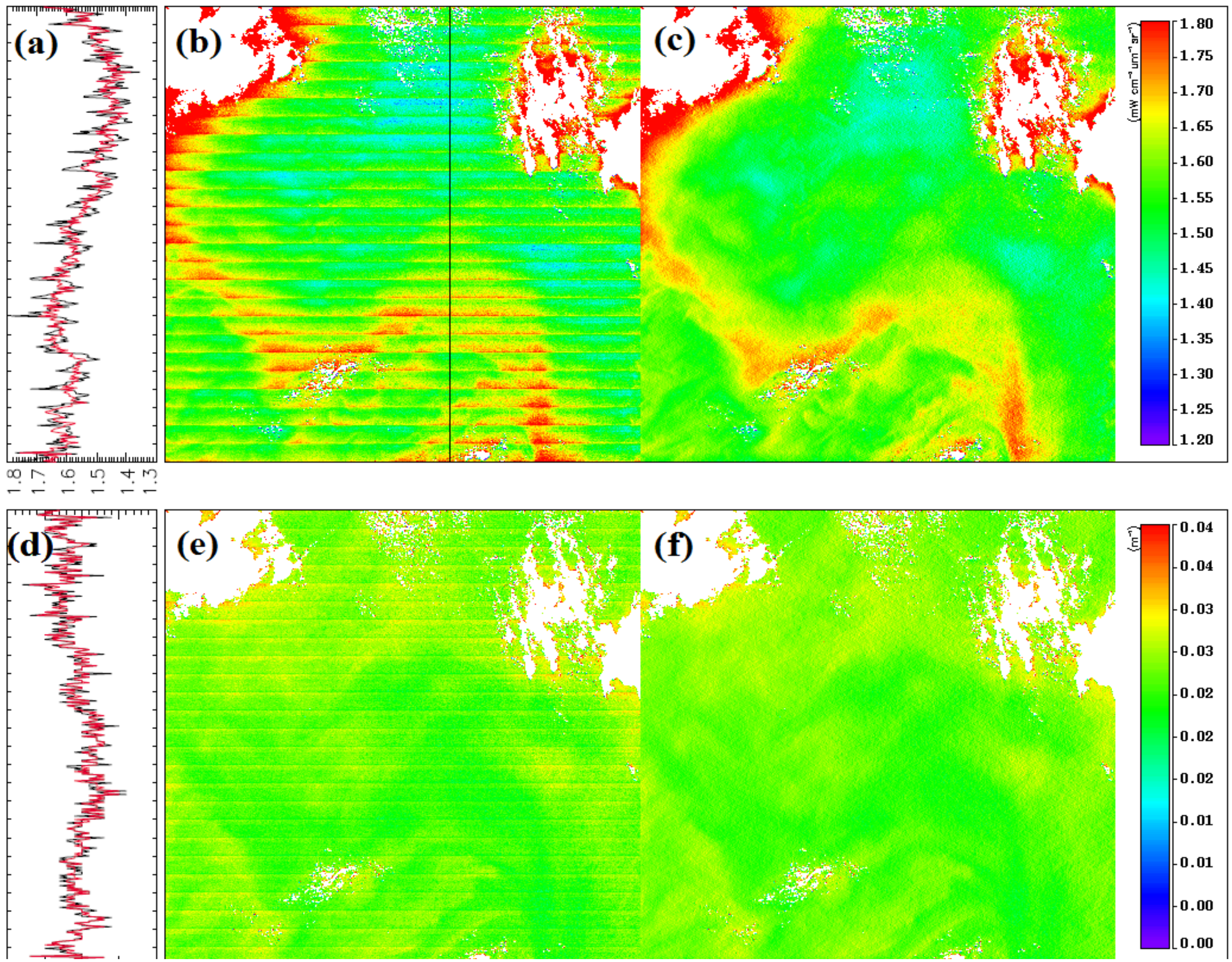


Comparisons of MODIS (a,b) and VIIRS-derived (c) $nL_w(\lambda)$ spectra as a function of wavelength for the four atmospheric correction algorithms, and (d) scatter plot of VIIRS-derived $nL_w(\lambda)$ at various wavelengths from the BMW against SWIR, randomly sampled from the entire VIIRS granule corresponding to the coverage plot (e).

Destriping of VIIRS Ocean Color Products (1)
(Implemented in MSL12) (Examples)

$nL_w(412)$

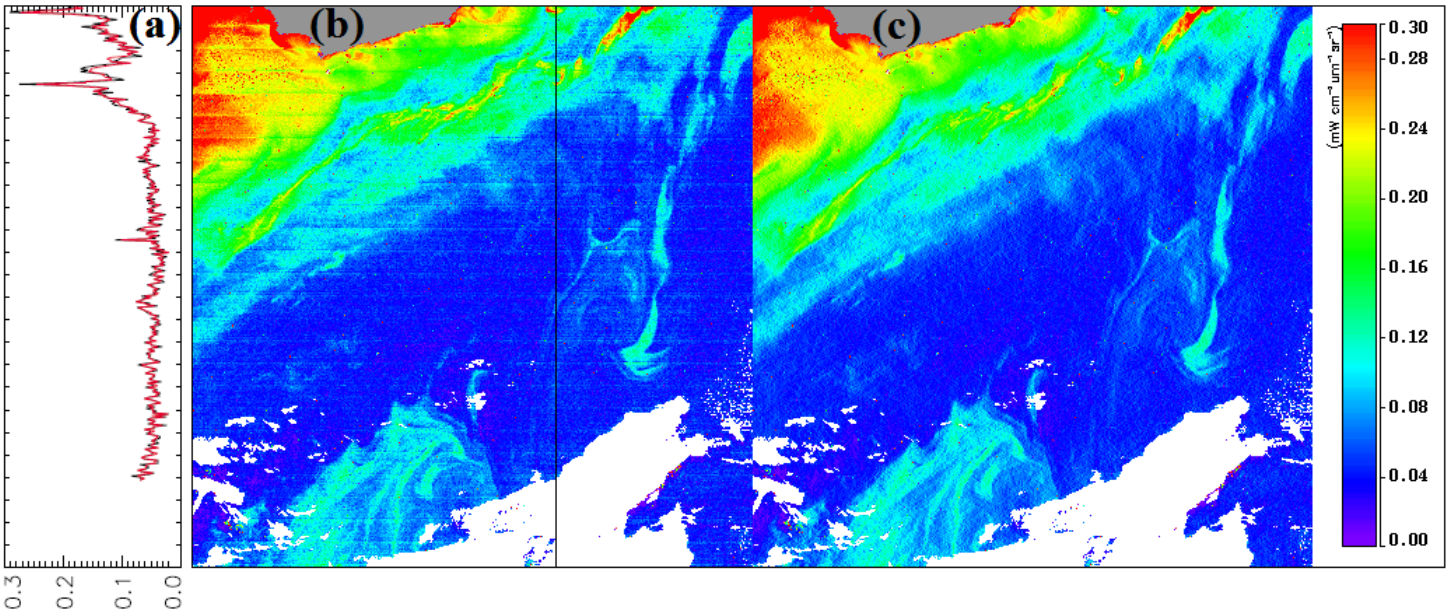
$K_d(490)$



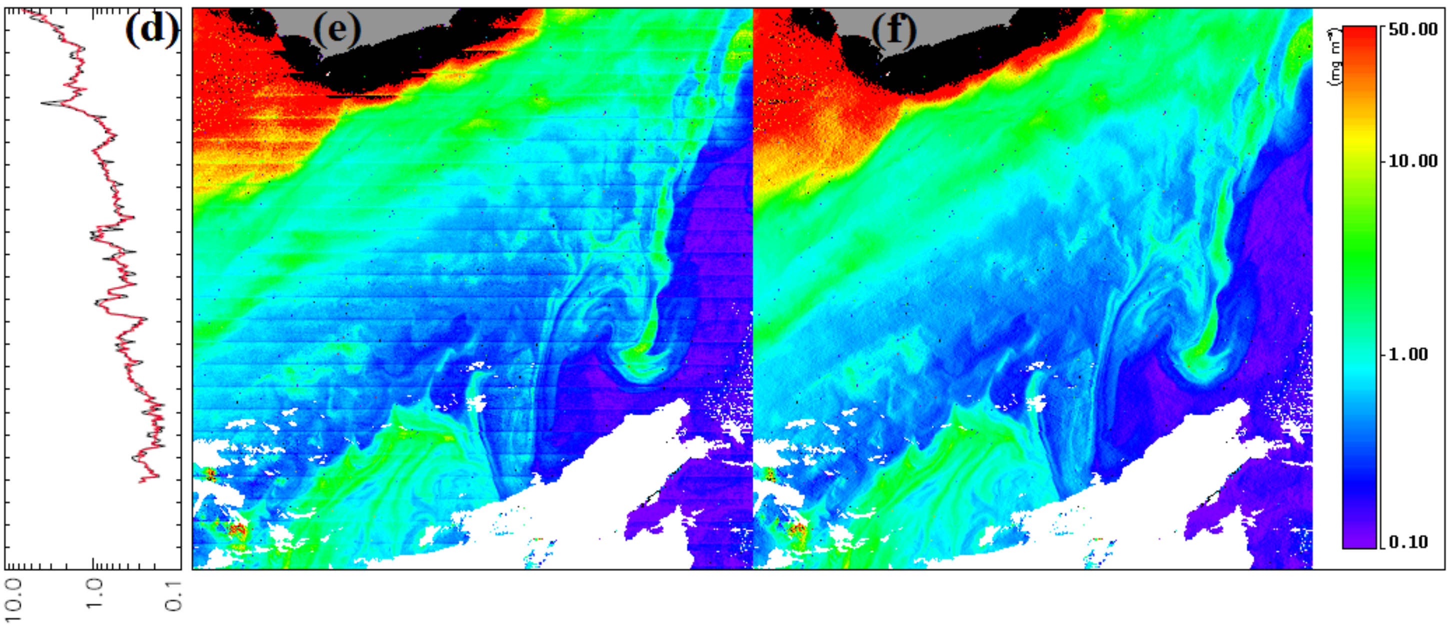
Mikelsons, K., M. Wang, L. Jiang, and M. Bouali, "Destriping algorithm for improved satellite-derived ocean color product imagery," *Opt. Express,* **22**, 28058-28070, 2014. http://dx.doi.org/10.1364/OE.22.028058

Destriping of VIIRS Ocean Color Products (2)
(Examples)

***nL_w*(671)**

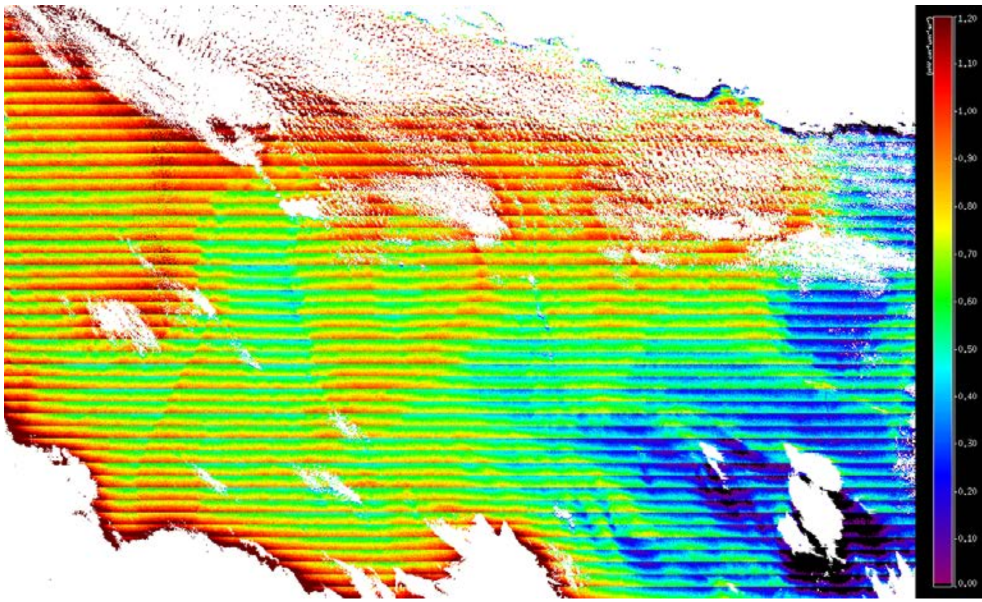


Chlorophyll-a

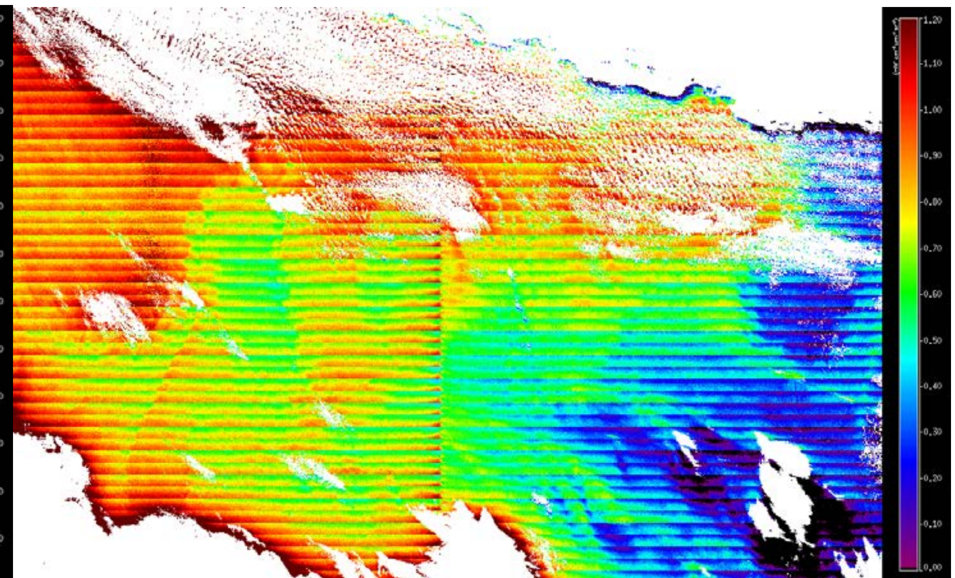


Polarization Correction (1)

Case Study: 04/14/2014 00:43 UTC



nL_w(412) without polarization correction

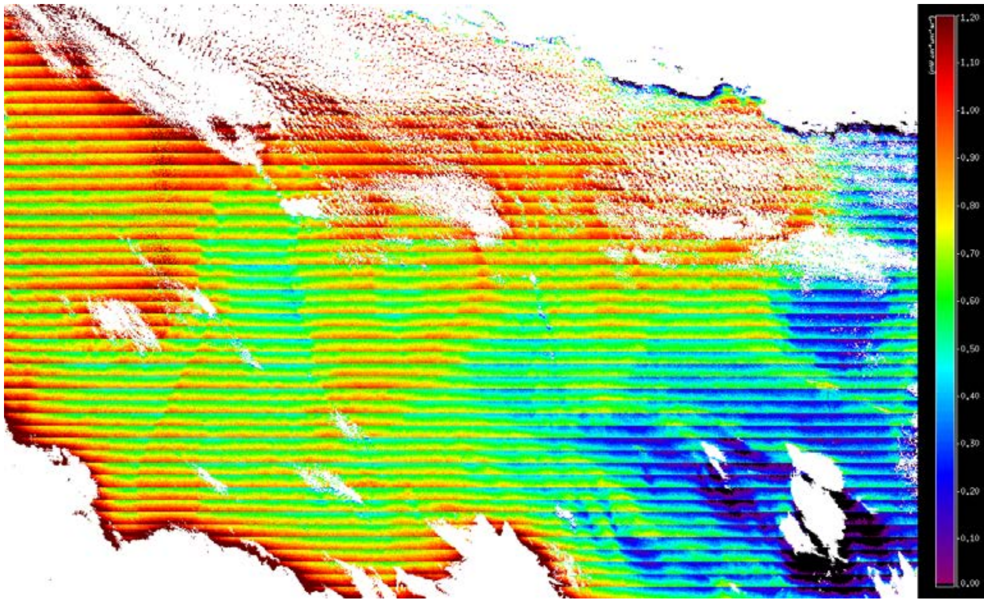


nL_w(412) with **old** polarization correction

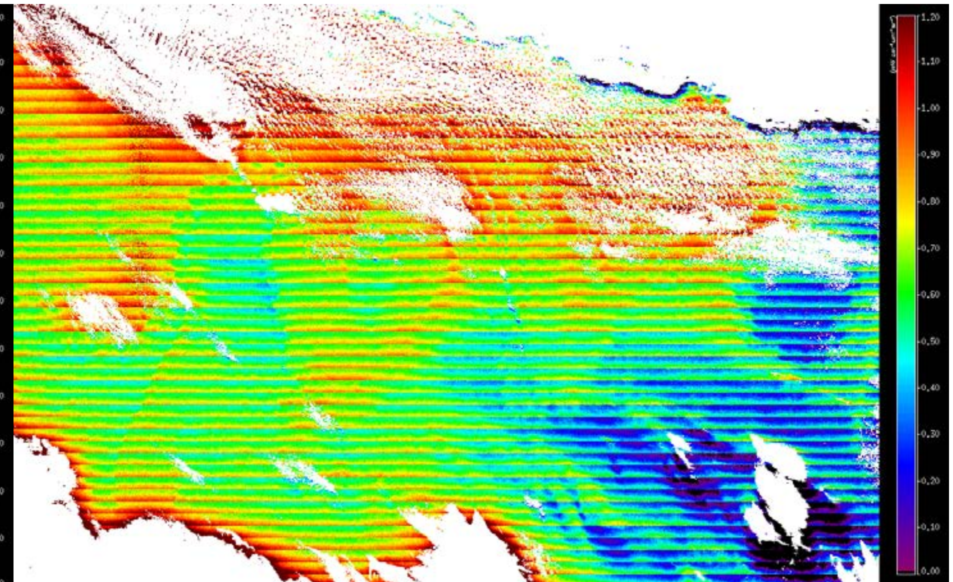
VIIRS Granule at 55°S and 155°W in South Pacific Ocean

Polarization Correction (2)

Case Study: 04/14/2014 00:43 UTC



nL_w(412) without polarization correction

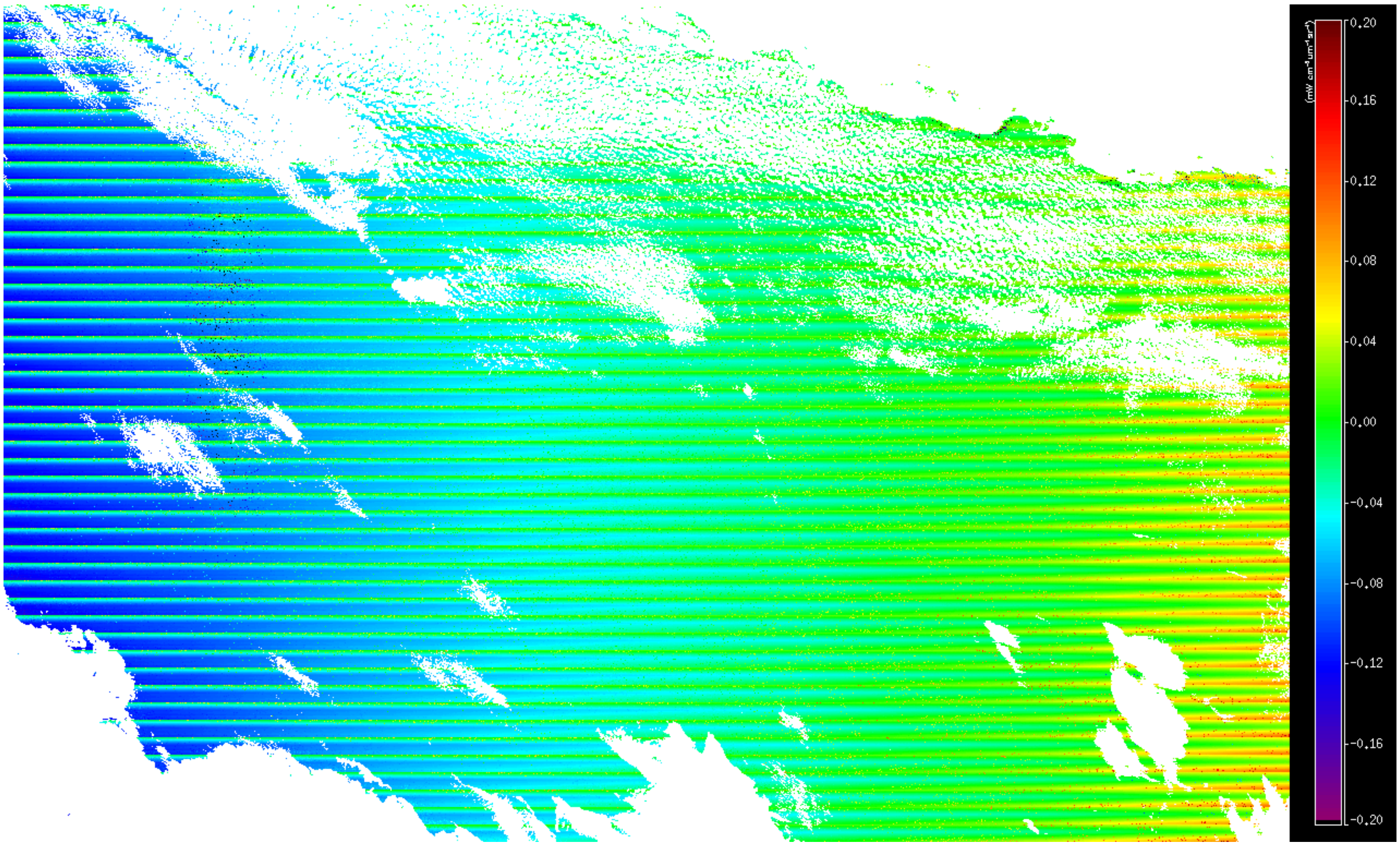


nL_w(412) with **new** polarization correction

VIIRS Granule at 55°S and 155°W in South Pacific Ocean

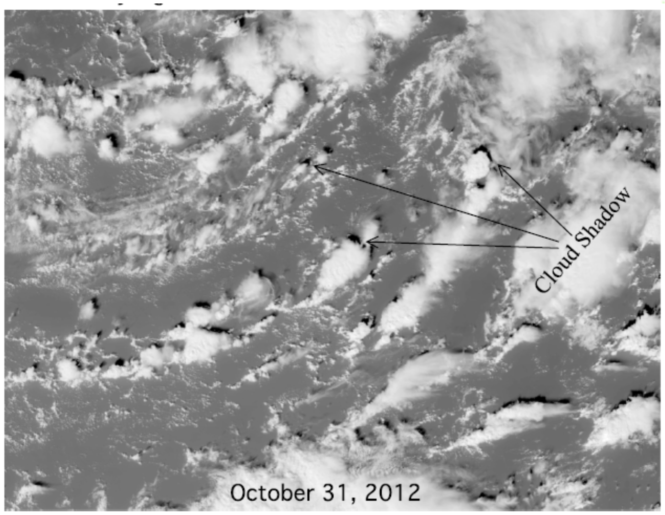
Polarization Correction (3)

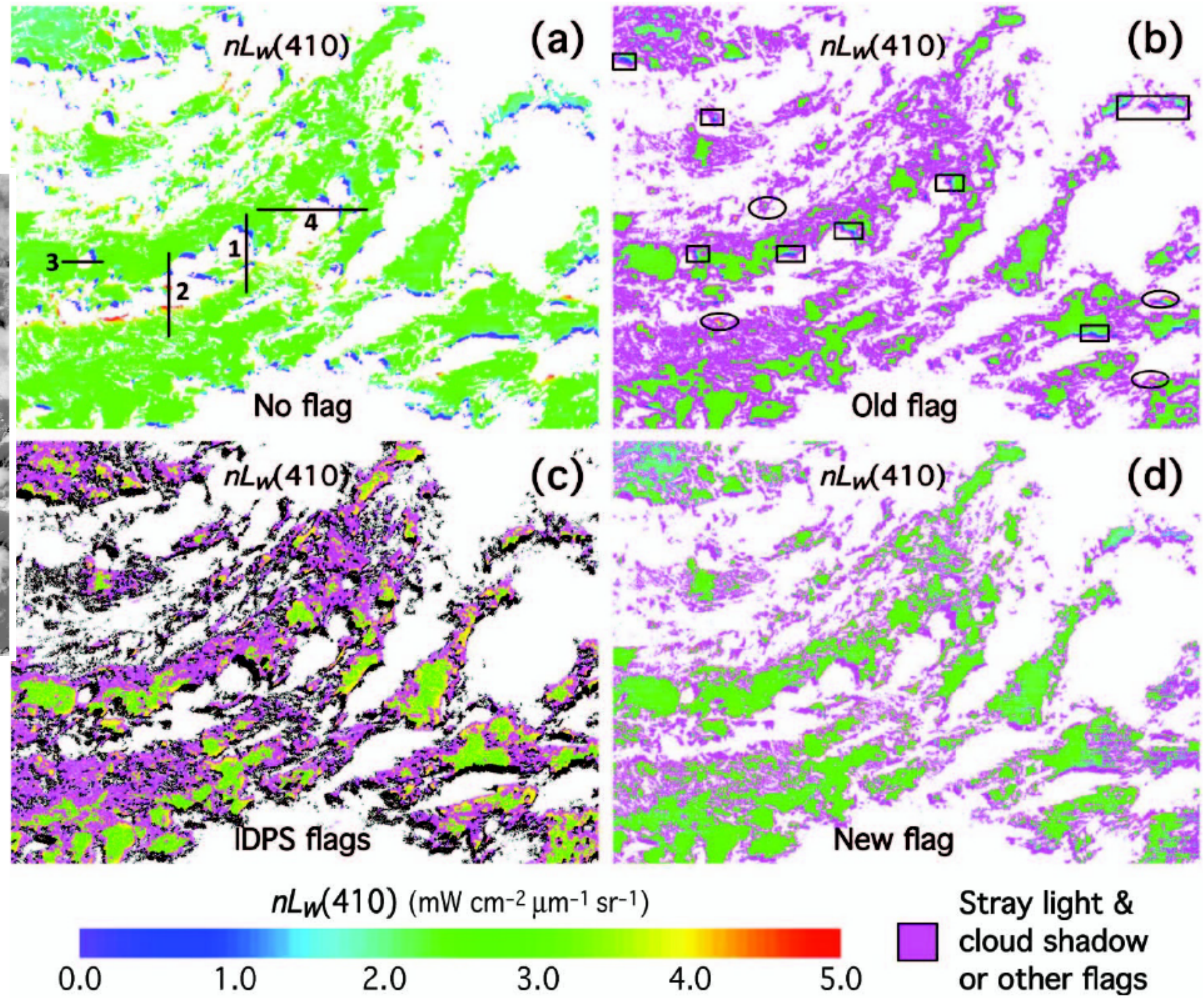
Difference = nL_w(412, polcor) – nL_w(412, nopolcor)



nL_w(412, polcor) increased in the right side, make it more uniform

Stray Light & Cloud Shadow Effects (1)
(Implemented in MSL12)

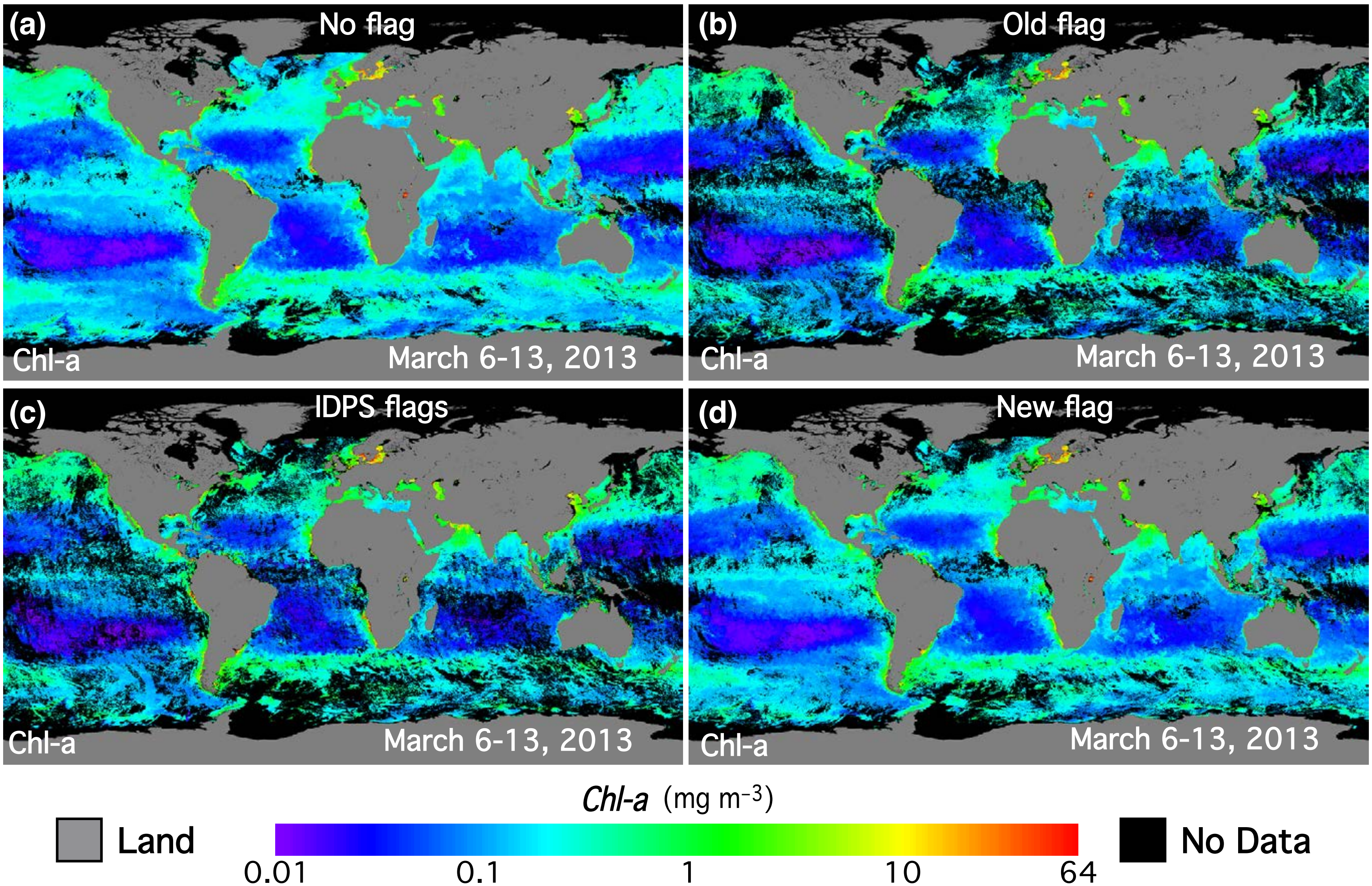




Jiang, L. and M. Wang, "Identification of pixels with stray light and cloud shadow contaminations in the satellite ocean color data processing," *Appl. Opt.*, **52**, 6757–6770, 2013. http://dx.doi.org/10.1364/AO.52.006757

Stray Light & Cloud Shadow Effects (2)

VIIRS chlorophyll-a global 8-day composite images



MSL12 VIIRS Ocean Color EDR Evaluations

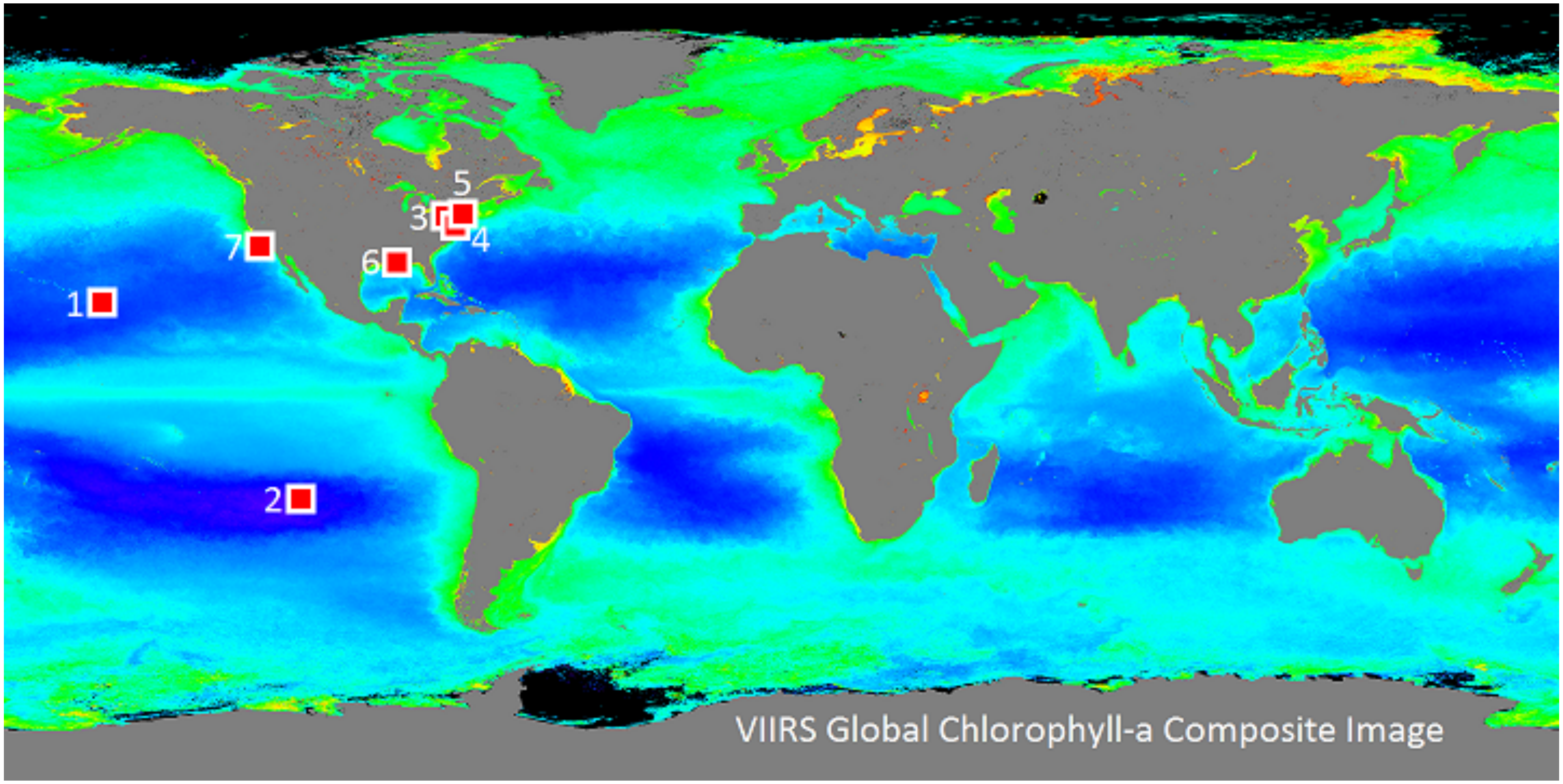
Three VIIRS ocean color data streams are evaluated:

- **Current** (global mission-long data):
  - MSL12 version in 2014 (running routinely from beginning of the mission and delivered to CoastWatch in May 2014)
  - Using IDPS SDR
- **New EDR** (reprocessed global mission-long data):
  - MSL12 version in 2015 (with improved/updated algorithms)
  - Using IDPS SDR
- **New SDR/EDR** (only for in situ matchup data):
  - MSL12 version in 2015 (with improved/updated algorithms)
  - Using improved SDR

VIIRS Ocean Color Product Evaluations

- MOBY
- AERONET-OC
- NOAA VIIRS Cal/Val Team dataset
- NASA SeaBASS dataset
- Compared with MODIS-Aqua at Hawaii and SPG
- VIIRS global images compared with those from MODIS-Aqua

VIIRS Ocean Color EDR Monitoring Sites

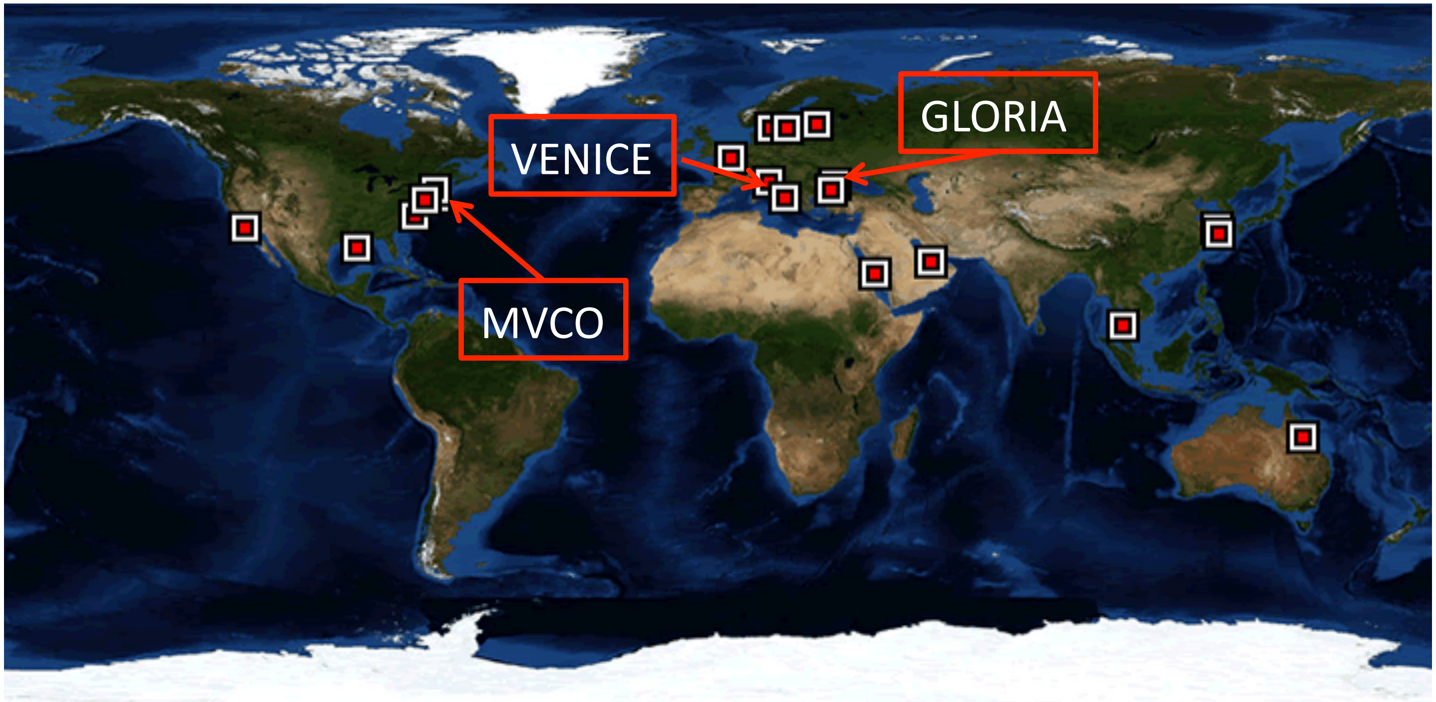


1. **MOBY Site**; 2. South Pacific Gyre; 3. Chesapeake Bay; 4. US East Coast; 5. **AERONET-OC CSI Site**; 6. **AERONET-OC LISCO Site**; 7. **AERONET-OC USC Site**.

Website:

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

AERONET-OC Sites



AERONET-OC data were obtained at:
http://aeronet.gsfc.nasa.gov/new_web/ocean_color.html
We thank AERONET-OC PIs for contributing useful ocean color radiance data.

AERONET-OC Site Information

(Used for the VIIRS OC EDR Evaluations)

Site	Full Name	Location	Lon/Lat	Elevation	PI
CSI	WaveCIS_CSI[1]	Gulf of Mexico	28.867°N 90.483°W	32.7 m	Bill Gibson Alan Weidemann
LISCO	Long Island Sound Coastal Observatory	2 miles off shore on Western Long Island Sound	40.955° N 73.342°W	12.0 m	Sam Ahmed Alex Gilerson
USC	Univ. Southern California SEAPRISM[2]	18 km off the coast of Newport Beach, CA	33.564°N 118.118°W	31.0 m	Burton Jones Curtis Davis
GLORIA	GLORIA[3]	12 nautical miles from Romanian Coast	44.600°N 29.360°E	30.0 m	Giuseppe Zibordi

[1]Wave-Current-Surge Information System for Coastal Louisian, Coastal Studies Institute – Lousiana State University

[2]SeaWiFS Photometer Revision for Incident Surface Measurements (SeaPRISM)

[3]Romanian offshore (Oil) Drilling Marine Platform called 'GLORIA'

Dedicated VIIRS Cal/Val Cruise

NOAA Ship *Nancy Foster*

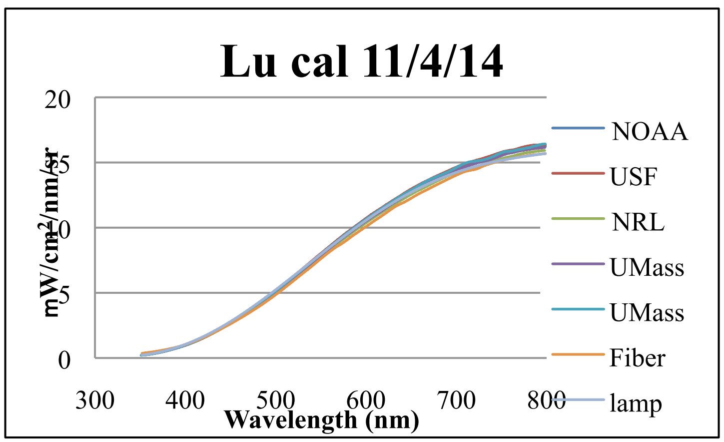
11-21 November 2014

International, Interagency, and Academic Collaborations:

4 US Agencies, EU-JRC, 6 Universities

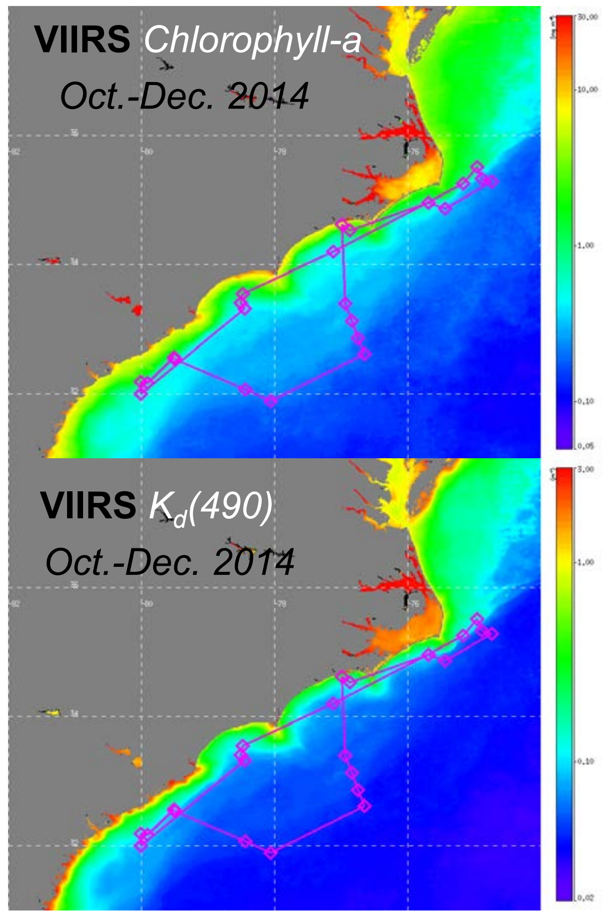
Validation Measurements

Water-leaving radiance; Chlorophyll-a; Absorption and backscattering coefficients; Bi-directional radiance distribution; Phytoplankton physiology; Carbon; Total suspended matter; Aerosol optical depth, etc.



Pre-cruise inter-calibration results for 5 radiance sensors

Cruise Track

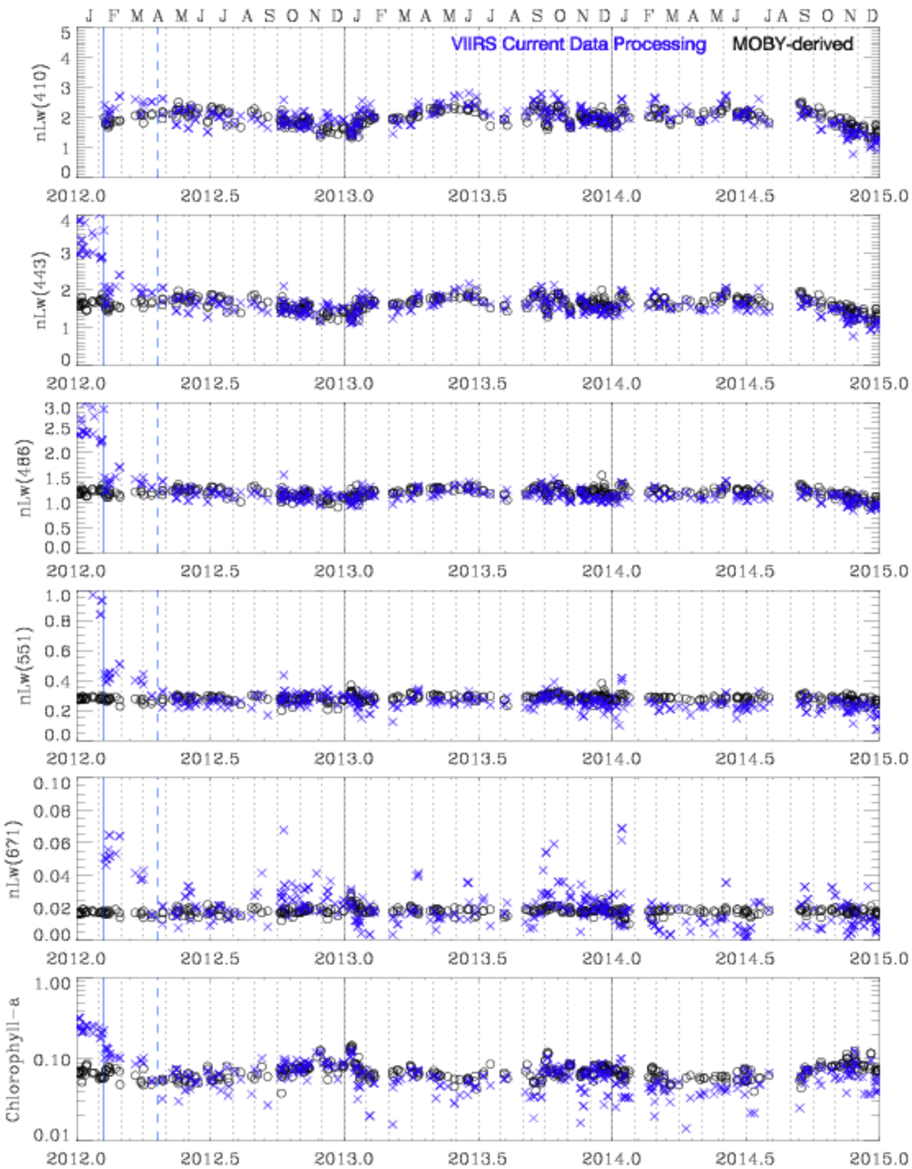


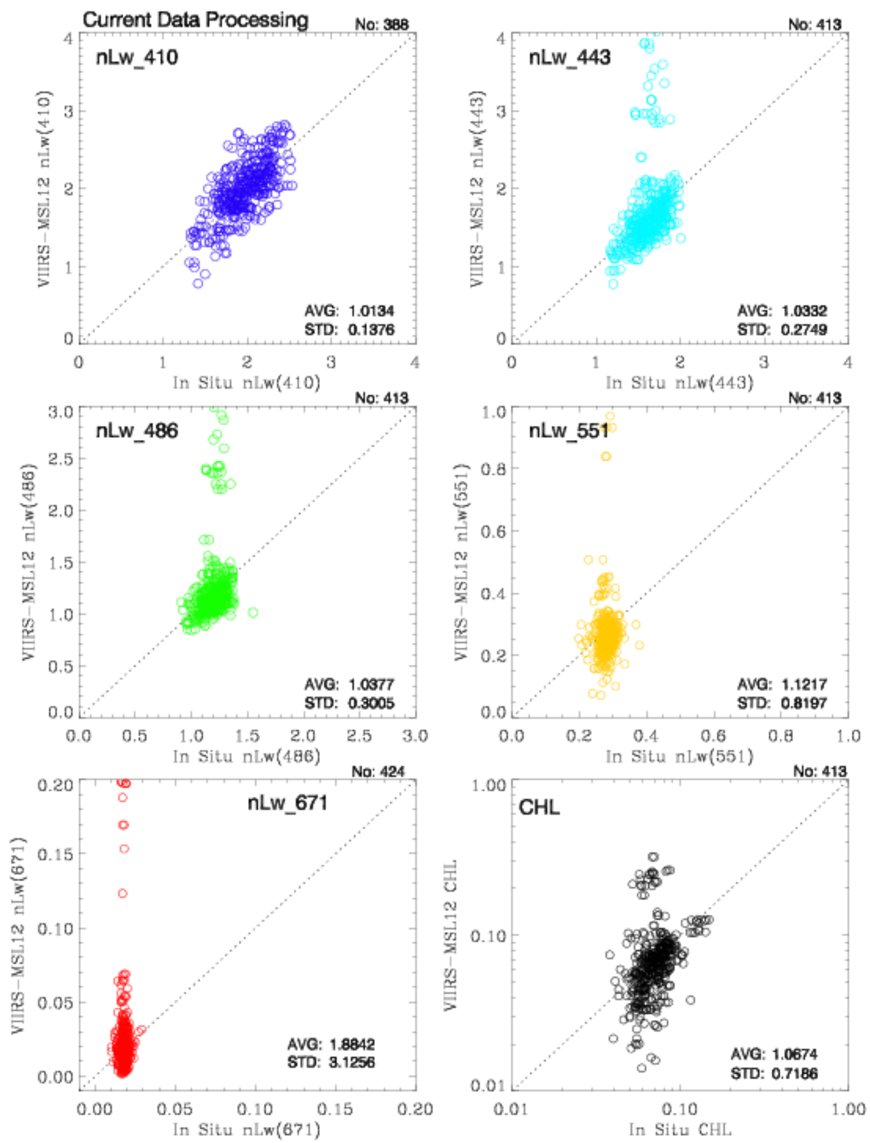
Validation Results

- **Occupied 23 stations over 10 days**
- **Simultaneous measurements at each station for:**
  - ✓ **4 profiling radiometers**
  - ✓ **2 floating radiometers**
  - ✓ **6 above-water radiometers**
- **Conducted pre- & post-cruise inter-calibrations**

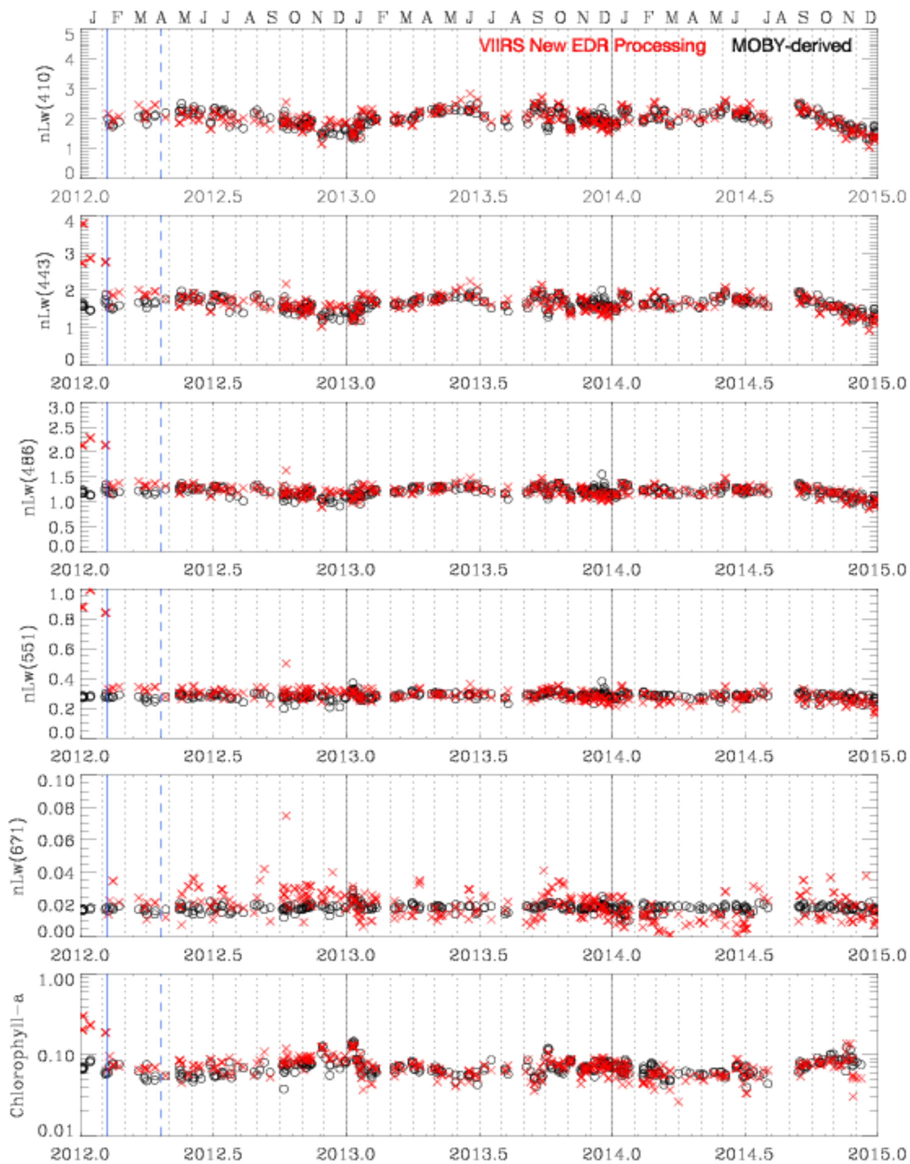
11 potential station matchups with VIIRS

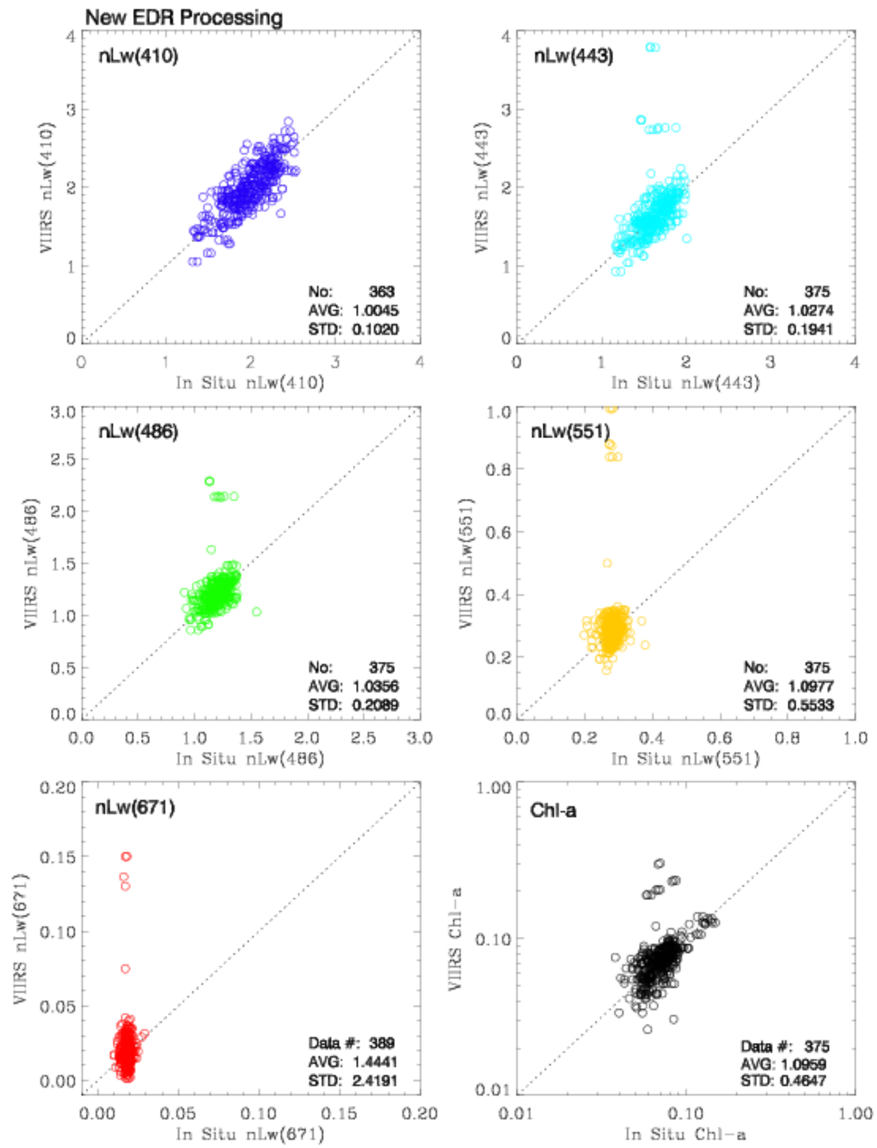
MOBY Comparison (Current)



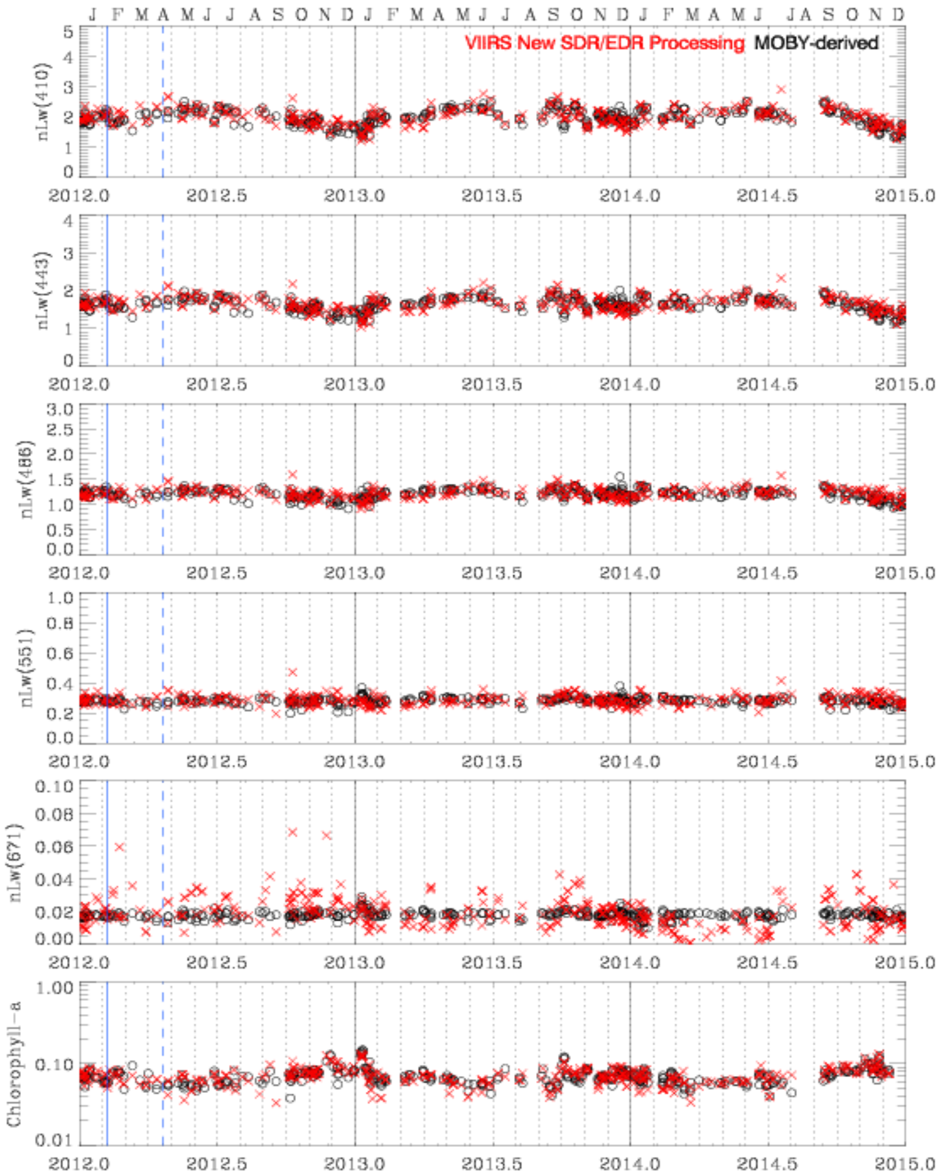


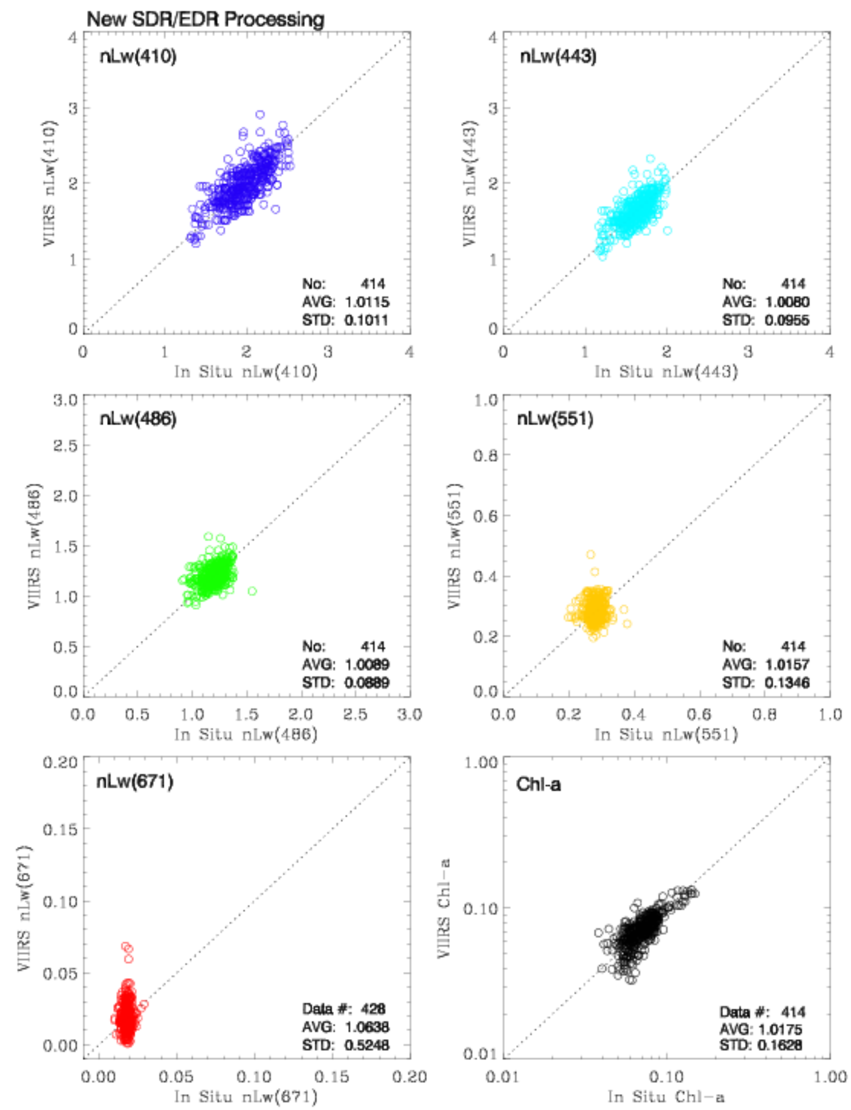
MOBY Comparison (New EDR)





MOBY Comparison (New SDR/EDR)





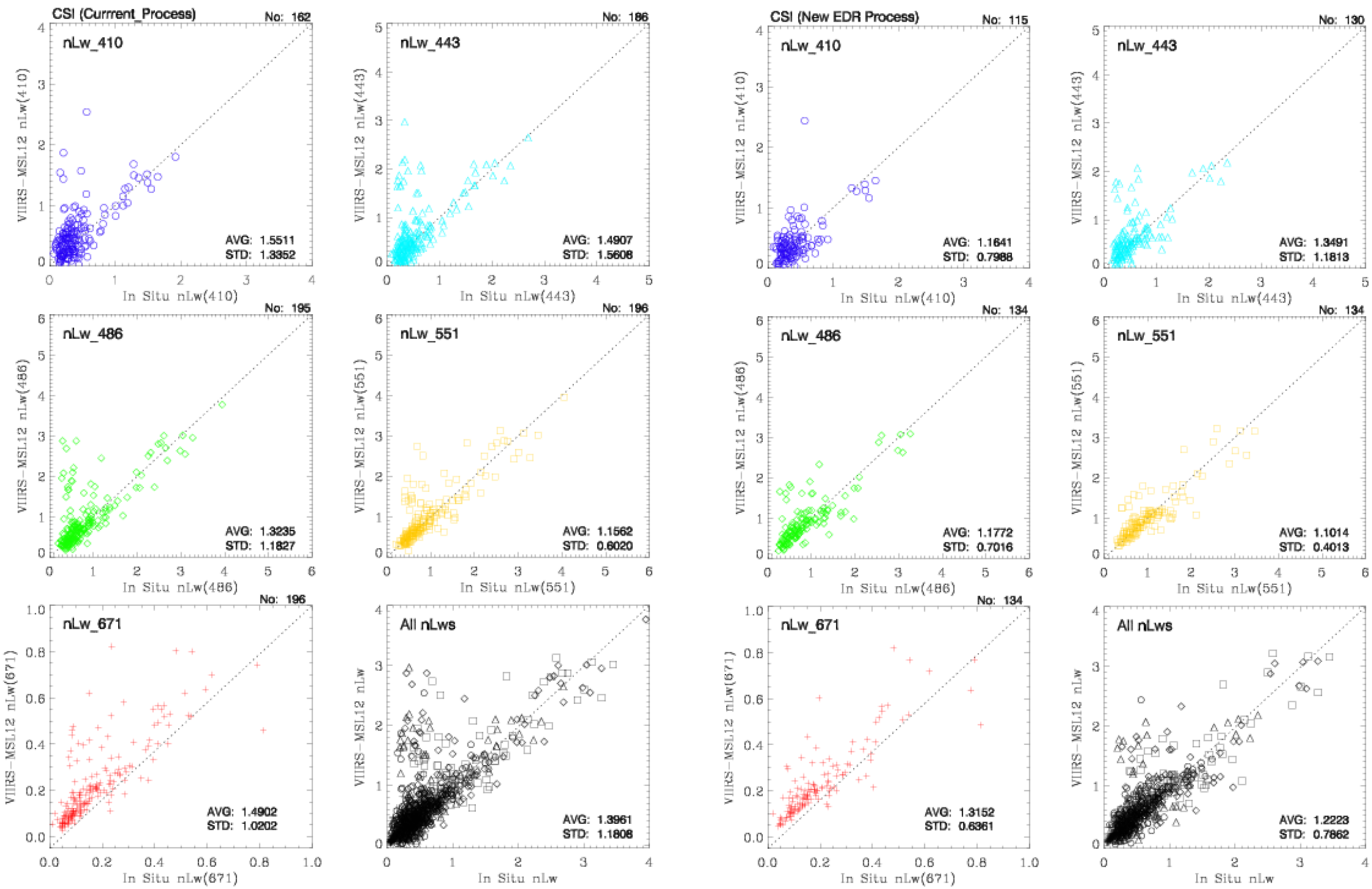
Quantitative Comparisons (MOBY)

Statistics of VIIRS MSL12 vs. In-Situ (MOBY)

	Current Data Processing				New EDR Processing (2015-03-12)				New SDR/EDR Processing (2015-02-23)			
	AVG	MED	STD	No	AVG	MED	STD	No	AVG	MED	STD	No
$nL_w(410)$	**1.0134**	1.0063	0.138	388	**1.0045**	1.0032	0.102	363	**1.0115**	1.0072	0.101	414
$nL_w(443)$	**1.0332**	0.9671	0.275	413	**1.0274**	1.0002	0.194	375	**1.0080**	1.0047	0.096	414
$nL_w(486)$	**1.0377**	0.9656	0.301	413	**1.0356**	1.0014	0.209	375	**1.0089**	1.0031	0.089	414
$nL_w(551)$	**1.1217**	0.9069	0.820	413	**1.0977**	0.9932	0.553	375	**1.0157**	1.0043	0.135	414
$nL_w(671)$	**1.8842**	1.0889	3.126	424	**1.4441**	1.0579	2.419	389	**1.0638**	0.9895	0.525	428
Chl-a	**1.0674**	0.9192	0.719	413	**1.0959**	1.0143	0.465	375	**1.0175**	1.0016	0.163	414
$K_d(490)$	**1.0322**	0.9538	0.409	413	**1.0460**	1.0107	0.261	462	**1.0075**	1.0077	0.100	414

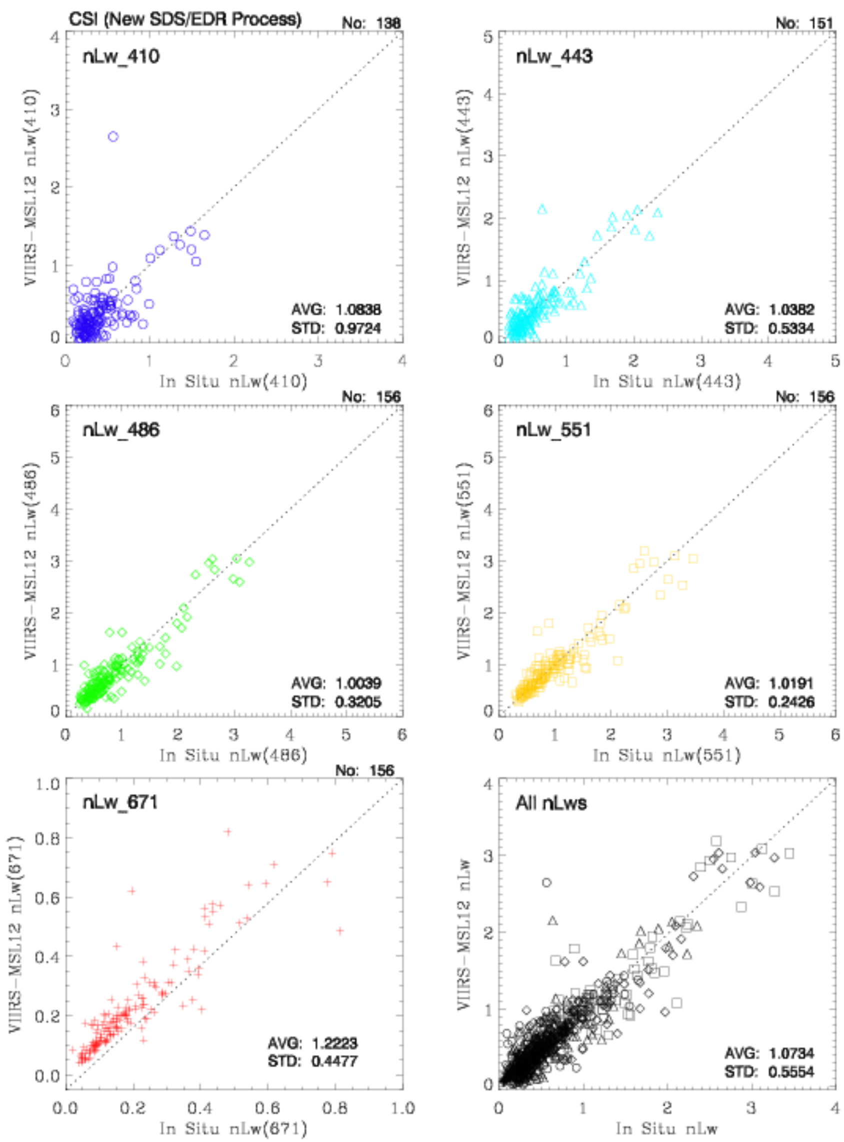
Improved with new MSL12 and new SDR/MSL12!

AERONET-OC Comparisons (CSI)
(Gulf of Mexico)



AERONET-OC Comparisons (CSI)

(Gulf of Mexico)



AERONET-OC Comparisons (CSI)

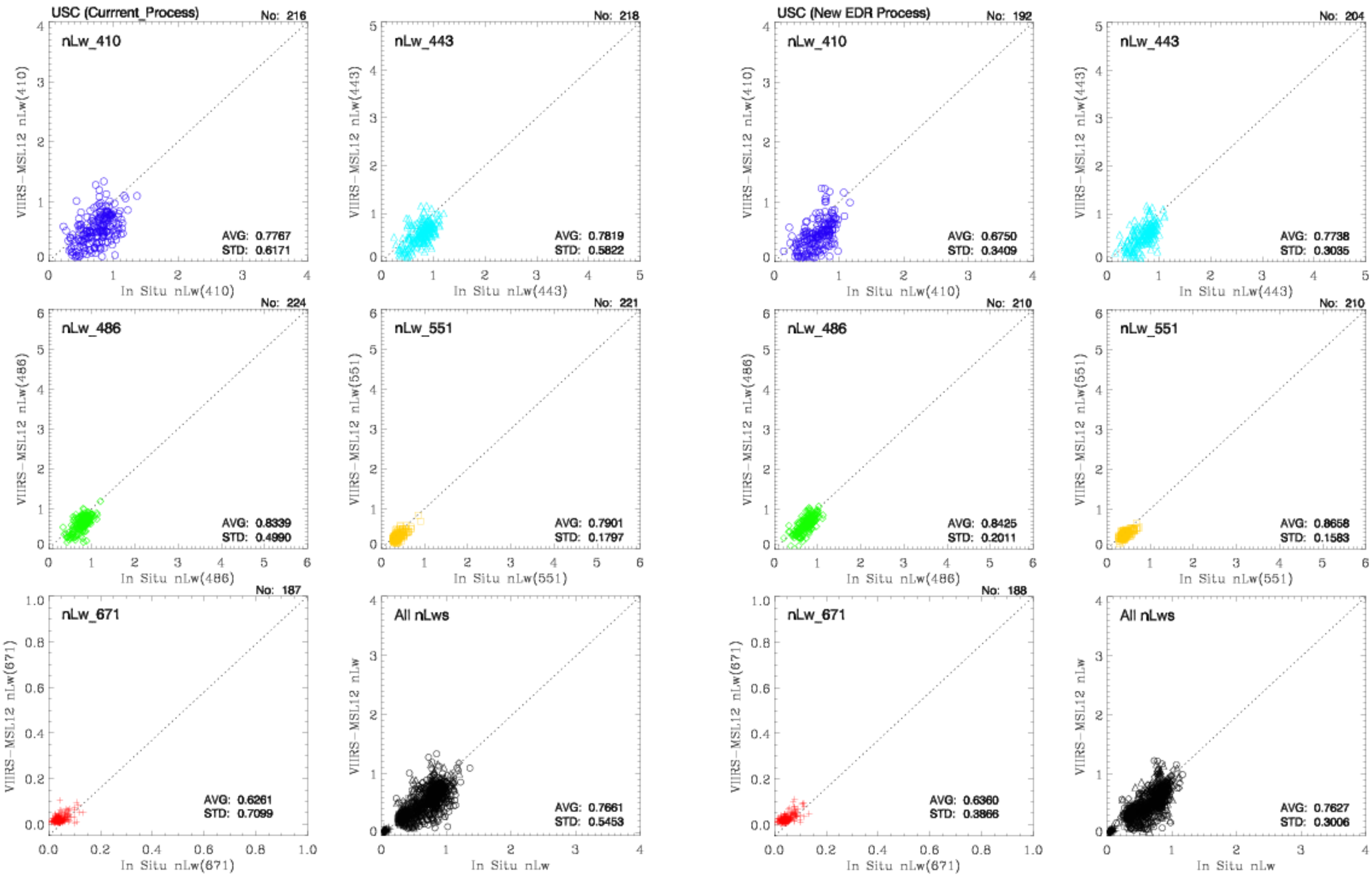
(Gulf of Mexico)

Statistics of VIIRS MSL12 vs. AERONET-OC (CSI)

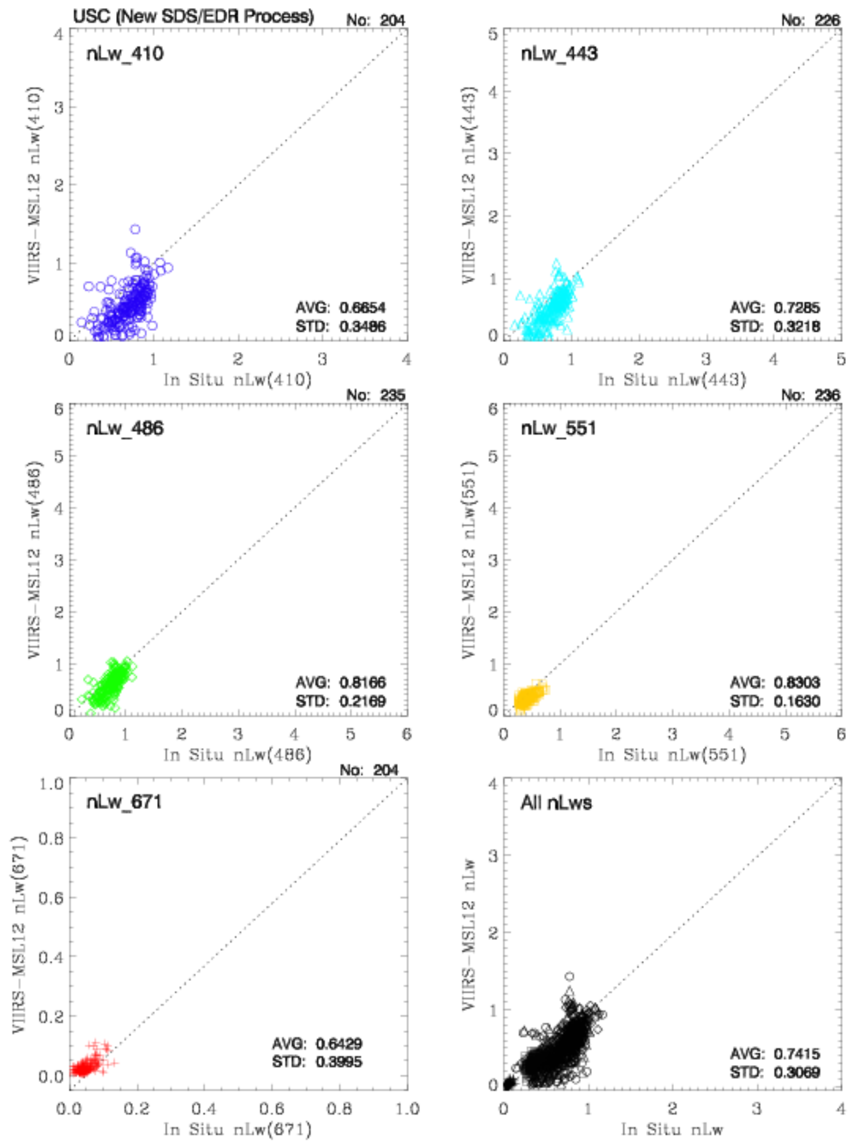
	Current Data Processing				New EDR Processing (2015-03-19)				New SDR/EDR Processing (2015-02-26)			
	AVG	MED	STD	No	AVG	MED	STD	No	AVG	MED	STD	No
$nL_w(410)$	**1.5511**	1.1097	1.335	162	**1.1641**	0.9379	0.799	115	**1.0838**	0.9051	0.972	138
$nL_w(443)$	**1.4907**	1.0314	1.561	186	**1.3491**	0.9913	1.181	130	**1.0382**	0.9306	0.533	151
$nL_w(486)$	**1.3235**	1.0129	1.183	195	**1.1772**	1.0097	0.702	134	**1.0039**	0.9455	0.321	156
$nL_w(551)$	**1.1562**	0.9946	0.602	196	**1.1041**	1.0141	0.401	134	**1.0191**	0.9762	0.243	156
$nL_w(671)$	**1.4902**	1.1878	1.020	196	**1.3152**	1.1646	0.636	134	**1.2223**	1.1412	0.448	156
nL_{w}_All	**1.3961**	1.0536	1.181	935	**1.2223**	1.0345	0.786	647	**1.0734**	0.9838	0.555	757

VIIRS data are **reasonably accurate** at Gulf of Mexico site (coastal).
Accuracy of nLws in average at M1-M4 is ~0-8%.

AERONET-OC Comparisons (USC)
(US West Coast)



AERONET-OC Comparisons (USC)
(US West Coast)



AERONET-OC Comparisons (USC)
(US West Coast)

Statistics of VIIRS MSL12 vs. AERONET-OC (USC)

	Current Data Processing				New EDR Processing				New SDR/EDR Processing			
	AVG	MED	STD	No	AVG	MED	STD	No	AVG	MED	STD	No
$nL_w(410)$	**0.7767**	0.7239	0.617	216	**0.6750**	0.6565	0.341	192	**0.6654**	0.6380	0.349	204
$nL_w(443)$	**0.7819**	0.7248	0.582	218	**0.7738**	0.7542	0.304	204	**0.7285**	0.7260	0.322	226
$nL_w(486)$	**0.8339**	0.8012	0.499	224	**0.8425**	0.8362	0.201	210	**0.8166**	0.8176	0.217	235
$nL_w(551)$	**0.7901**	0.7666	0.180	221	**0.8658**	0.8589	0.158	210	**0.8303**	0.8180	0.163	236
$nL_w(671)$	**0.6261**	0.4967	0.710	187	**0.6360**	0.5866	0.387	188	**0.6429**	0.5522	0.400	204
nL_{w}_All	**0.7661**	0.7400	0.545	1066	**0.7627**	0.7715	0.301	1004	**0.7630**	0.7446	0.776	1105

VIIRS data are **biased low** at USC site (coastal) by ~20-30%.

AERONET-OC Comparisons (LISCO)
(Long Island Sound)

Statistics of VIIRS MSL12 vs. AERONET-OC (LISCO)

	Current Data Processing				New EDR Processing				New SDR/EDR Processing			
	AVG	MED	STD	No	AVG	MED	STD	No	AVG	MED	STD	No
$nL_w(410)$	**1.7263**	1.1416	1.694	70	**1.4729**	0.9751	1.566	58	**1.4199**	0.8053	1.715	60
$nL_w(443)$	**1.1262**	0.6639	1.318	106	**0.9521**	0.5423	1.138	133	**0.6112**	0.4629	0.588	139
$nL_w(486)$	**0.7547**	0.6064	0.516	144	**0.7048**	0.6068	0.488	193	**0.6187**	0.5890	0.308	194
$nL_w(551)$	**0.8345**	0.7901	0.267	145	**0.8381**	0.7747	0.303	200	**0.7999**	0.7821	0.251	200
$nL_w(671)$	**0.8125**	0.7716	0.403	137	**0.7747**	0.7451	0.387	183	**0.7386**	0.7530	0.298	179
nL_{w}_All	**0.9655**	0.7443	0.918	602	**0.8572**	0.7169	0.750	767	**0.7543**	0.6943	0.625	772

VIIRS data are generally **biased low** at LISCO site (coastal) ~20-35%.

AERONET-OC Comparisons (GLORIA)
(Romanian Coast)

Statistics of VIIRS MSL12 vs. AERONET-OC (GLORIA)

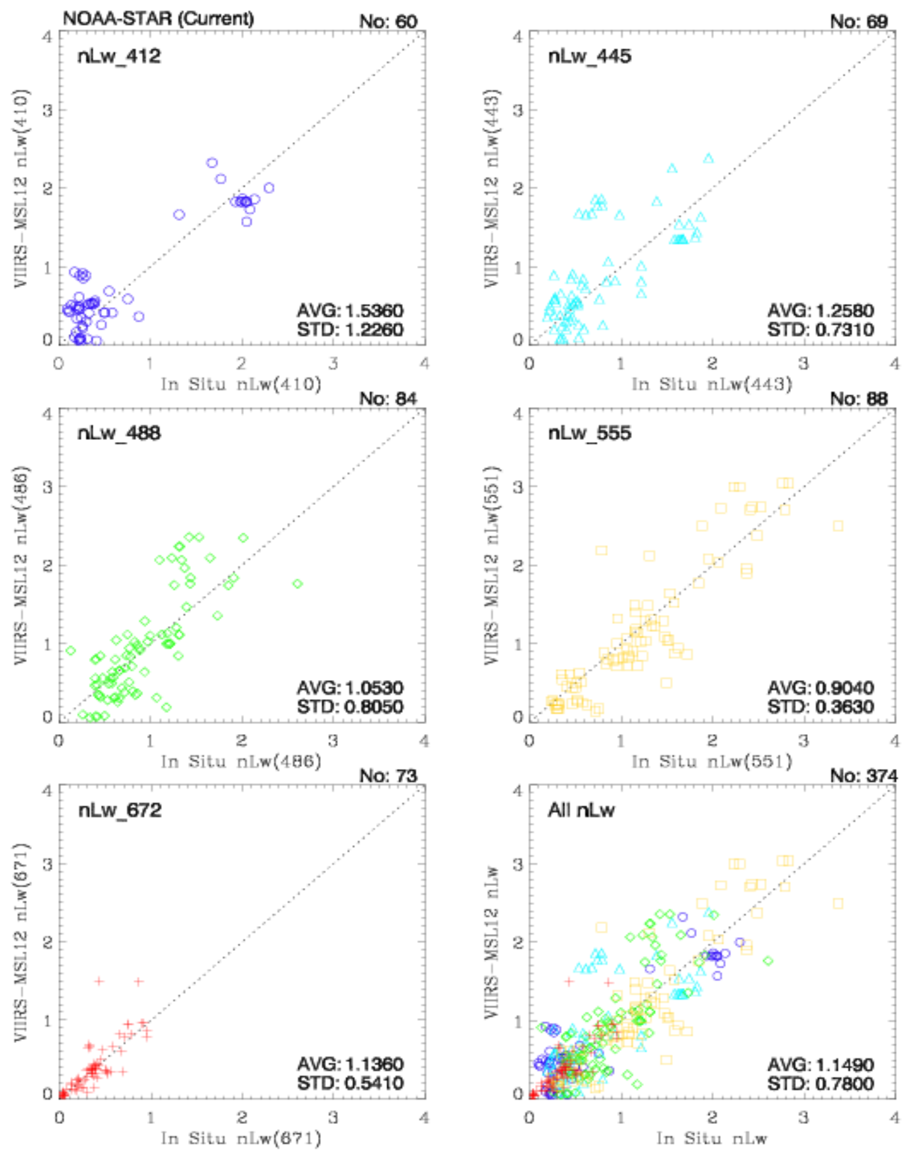
	Current Data Processing				New EDR Processing (2015-03-19)				New SDR/EDR Processing (2015-02-26)			
	AVG	MED	STD	No	AVG	MED	STD	No	AVG	MED	STD	No
nL_w(410)	**1.2920**	1.1170	0.811	144	**0.9955**	0.9002	0.678	181	**0.9672**	0.8044	0.722	203
nL_w(443)	**1.0587**	0.9640	0.498	147	**0.9895**	0.9418	0.412	203	**1.0038**	0.9364	0.477	226
nL_w(486)	**0.9956**	0.9341	0.484	148	**0.9666**	0.9565	0.212	207	**0.9988**	0.9545	0.452	230
nL_w(551)	**0.9722**	0.9167	0.433	147	**0.9603**	0.9537	0.139	205	**0.9837**	0.9369	0.364	228
nL_w(671)	**0.8941**	0.8685	0.329	146	**0.8963**	0.8970	0.271	206	**0.9573**	0.9151	0.653	229
nL_w_All	**1.0541**	0.9232	0.645	732	**0.9607**	0.9322	0.383	1002	**0.9825**	0.9276	0.545	1116

VIIRS data are **excellently** matched with in situ data at GLORIA site (coastal).
Accuracy of nLws in average at M1-M5 is ~0-5%!!

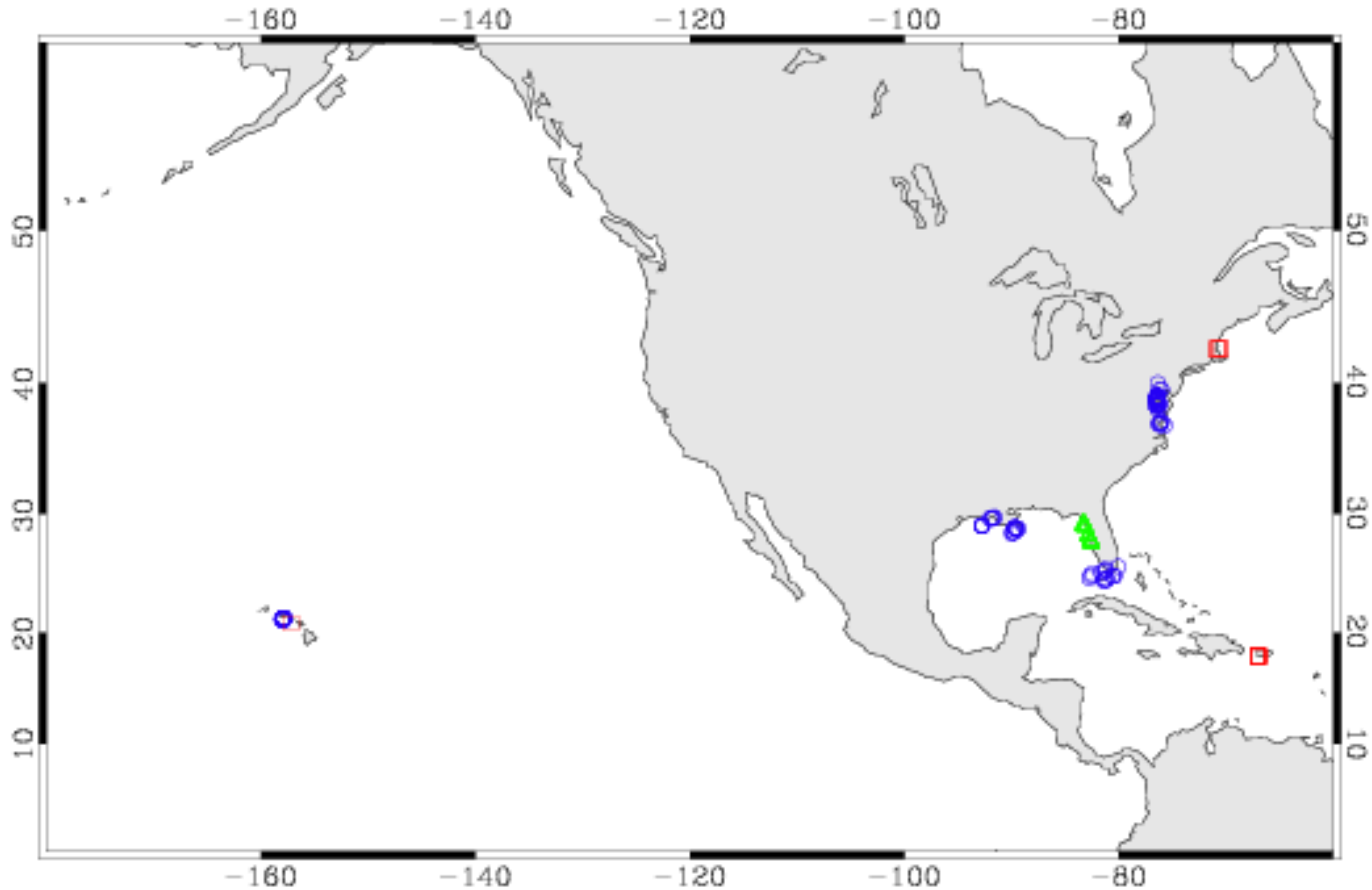
Matchup Comparisons of
In Situ Data from VIIRS Ocean Color Cal/Val Team

- **<u>Mike Ondrusek & Eric Stengel</u>**: Chesapeake Bay, Florida Key, Gulf of Mexico, Hawaii, Puerto Rico.
- **<u>Chuanmin Hu</u>**: Florida (west) Coast.
- **<u>Zhongping Lee</u>**: Massachusetts Bay, MOBY site, Puerto Rico.

Total data number: ~290 points (in situ optics nLws).



Locations of in situ radiometric measurements by NOAA Ocean Color Cal/Val Team

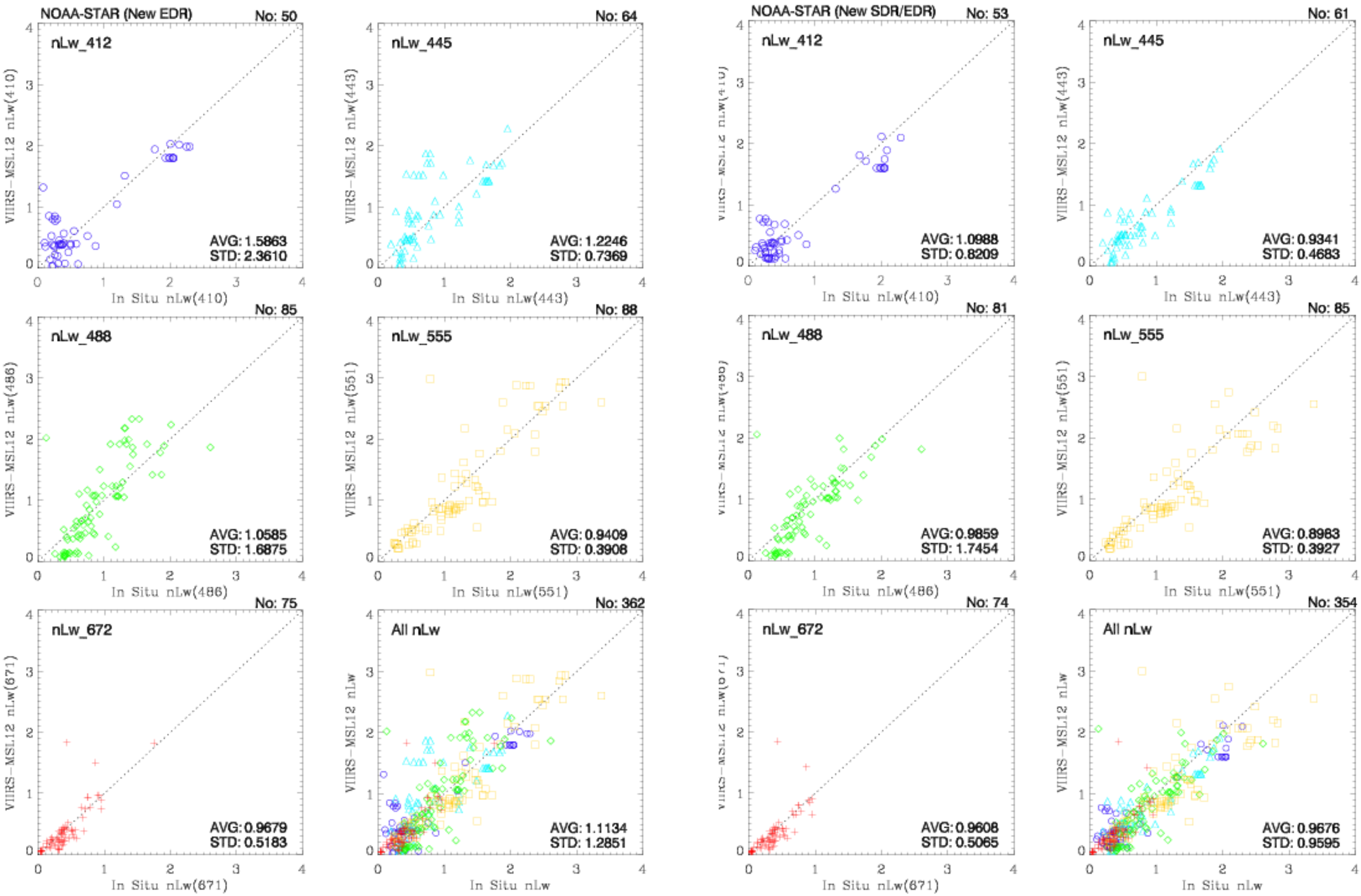


○ NOAA-STAR (M. Ondrusek)

△ USF (C. Hu)

□ UMB (Z. Lee)

Matchup Comparisons of In Situ Data from VIIRS Ocean Color Cal/Val Team

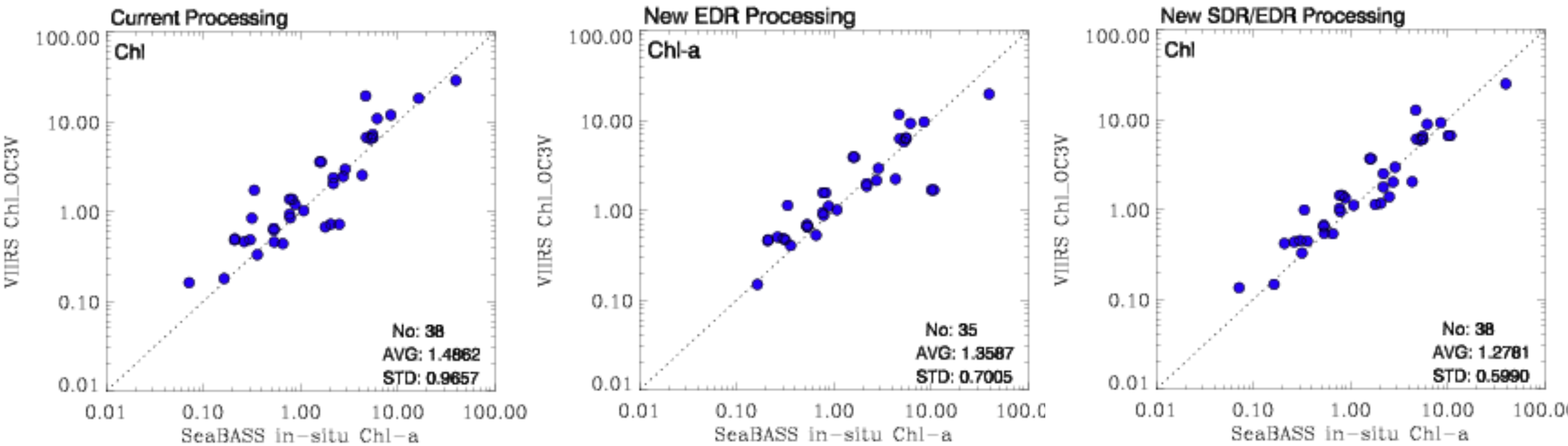


Matchup Comparisons of In Situ Data from VIIRS Ocean Color Cal/Val Team

	Current Data Processing				New EDR Processing (2015-03-19)				New SDR/EDR Processing (2015-02-26)			
	AVG	**MED**	**STD**	**No**	**AVG**	**MED**	**STD**	**No**	**AVG**	**MED**	**STD**	**No**
$nL_w(410)$	**1.5360**	0.9980	1.226	60	**1.5863**	0.9438	2.361	50	**1.0988**	0.8567	0.821	53
$nL_w(443)$	**1.2580**	1.0290	0.731	69	**1.2246**	0.9869	0.737	64	**0.9341**	0.9109	0.468	61
$nL_w(486)$	**1.0530**	0.9620	0.805	84	**1.0585**	0.8927	1.688	85	**0.9859**	0.8412	1.745	81
$nL_w(551)$	**0.9040**	0.8950	0.363	88	**0.9409**	0.8946	0.391	88	**0.8983**	0.8086	0.393	85
$nL_w(671)$	**1.1360**	1.0450	0.541	73	**0.9679**	0.9632	0.518	75	**0.9608**	0.9519	0.507	74
nL_w_All	**1.1490**	0.9620	0.780	374	**1.1134**	0.9303	1.285	362	**0.9676**	0.8567	0.960	354

Improved with new MSL12 and new SDR/MSL12.
Accuracy for nLws M1-M5 in average is in ~5-10%.

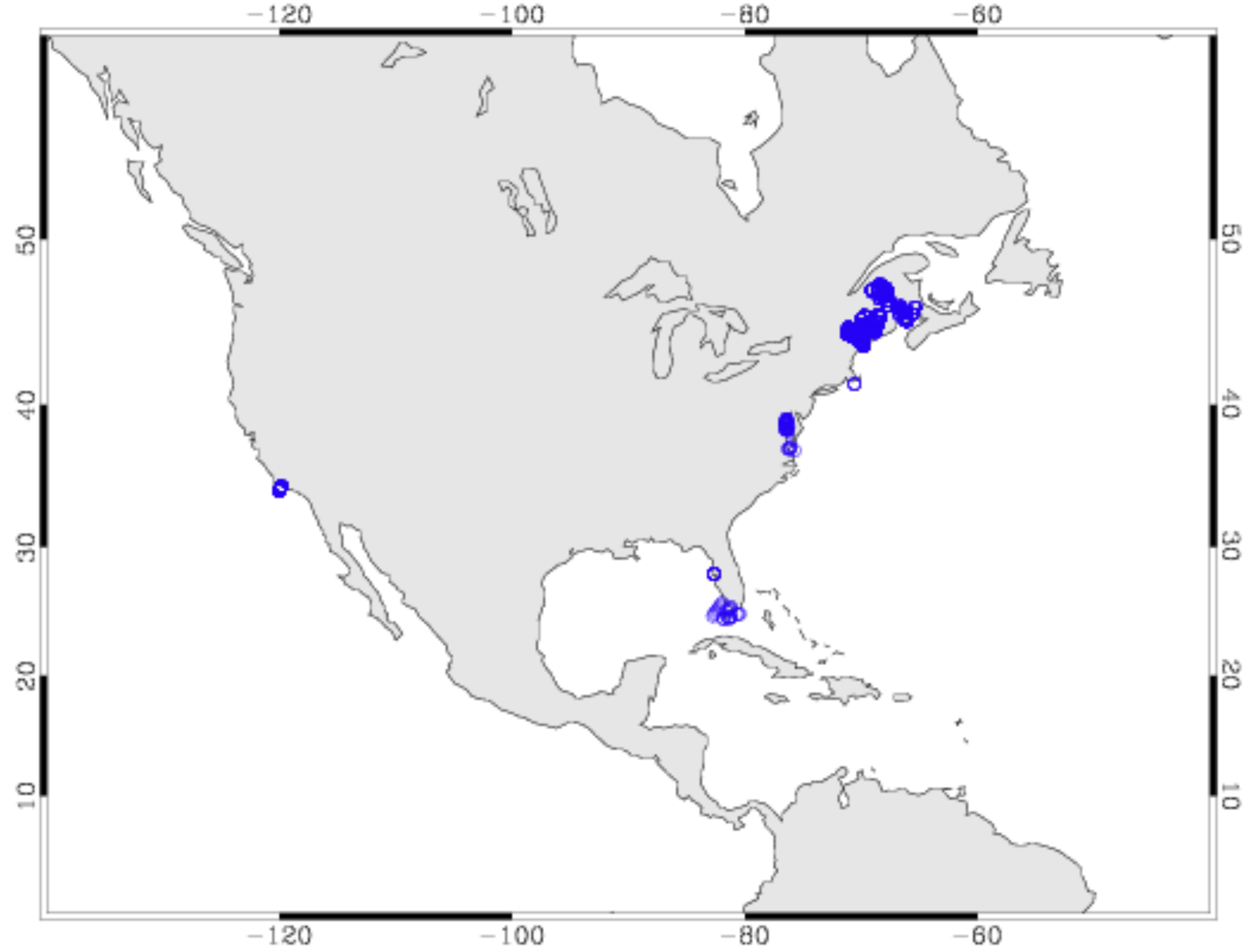
Matchup Comparison of SeaBASS Chl-a

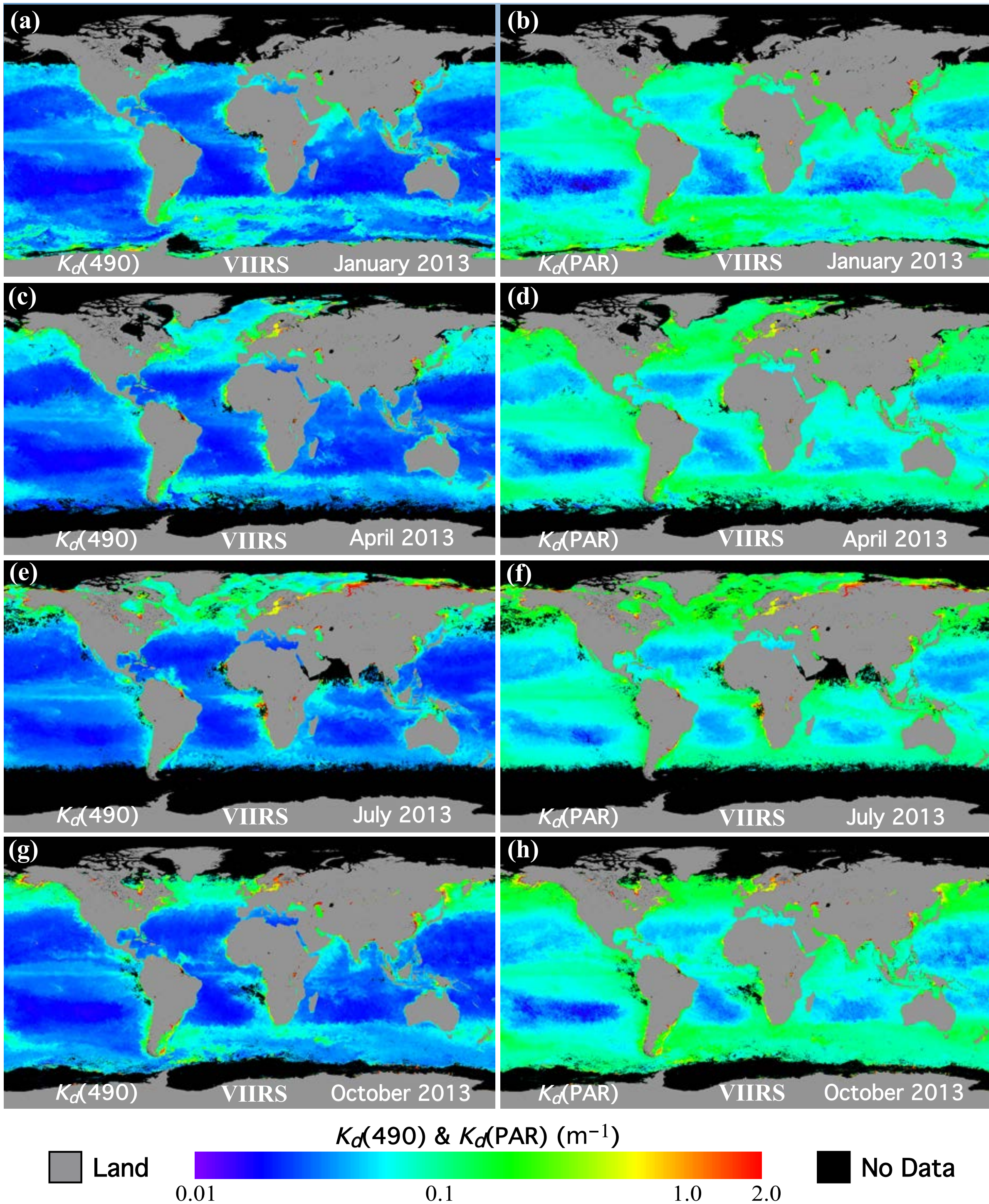


	Ratio of OC3V/Chl			OC3V vs Chl			log(OC3V) vs log(Chl)			No
	AVG	MED	STD	Slope	Intcpt	R^2	Slope	Intcpt	R^2	
Current Data Processing	1.4862	1.2273	0.966	0.812	1.225	0.78	0.866	0.112	0.81	38
New EDR Processing (2015-03-19)	1.3587	1.2210	0.701	0.487	1.391	0.66	0.743	0.102	0.77	35
New SDR/EDR Processing (2015-02-26)	1.2781	1.1933	0.599	0.652	1.099	0.83	0.857	0.085	0.89	38

Improved with new MSL12 and new SDR/MSL12.
Accuracy for Chl-a is within ~30% for Chl-a of 0.1 to ~30 mg/m^3.

Locations of NASA SeaBASS in situ Chl-a for the VIIRS period





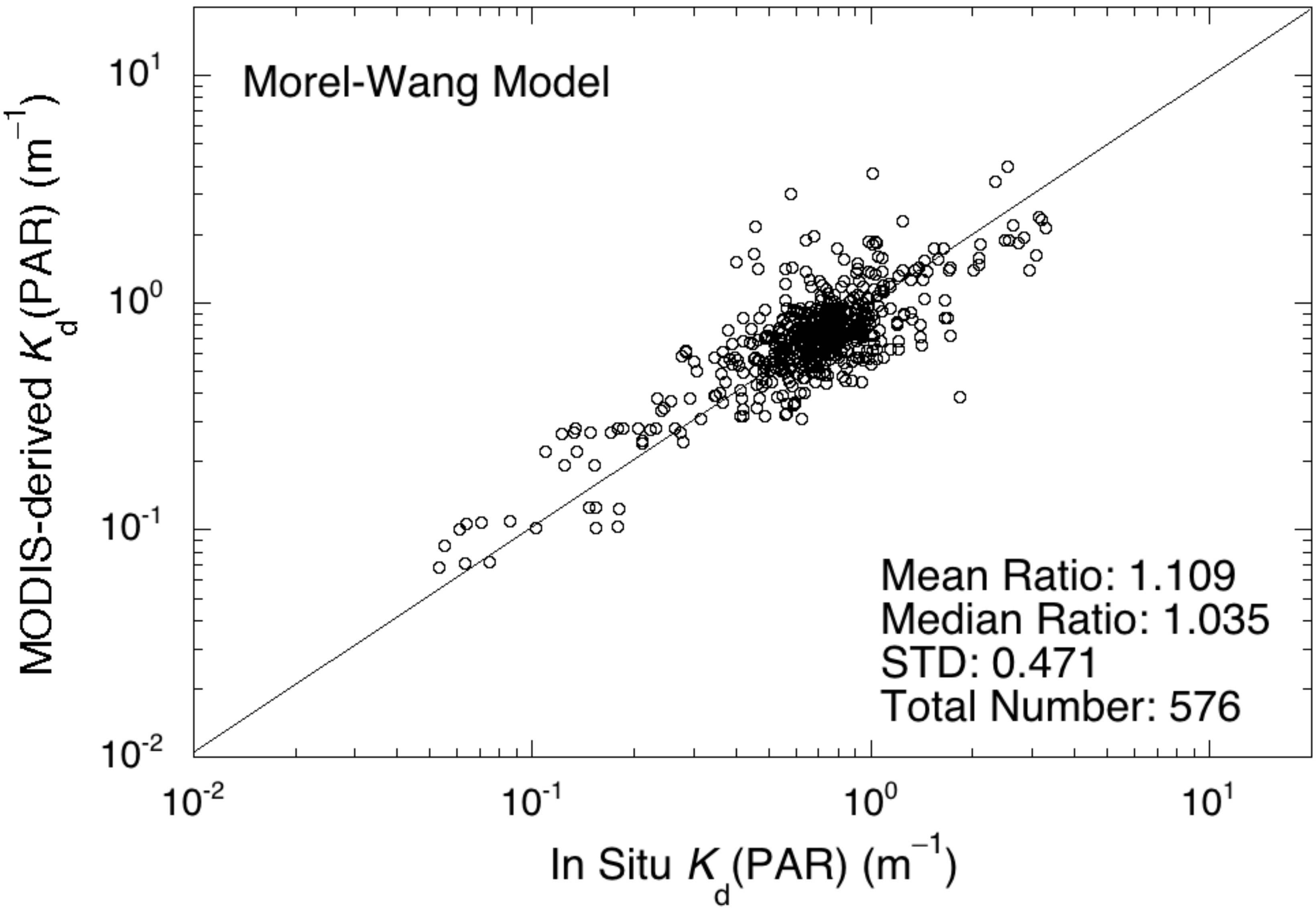
VIIRS K_d(490) and K_d(PAR)

VIIRS K_d(490) Product:
Wang, M., S. Son, and L. W. Harding, Jr., "Retrieval of diffuse attenuation coefficient in the Chesapeake Bay and turbid ocean regions for satellite ocean color applications", *J. Geophys. Res.*, **114**, C10011 (2009). doi:10.1029/2009JC005286

VIIRS K_d(PAR) Product:
Son, S. and M. Wang, "Diffuse attenuation coefficient of the photosynthetically available radiation K_d(PAR) for global open ocean and coastal waters", *Remote Sens. Environ.*, **159**, 250-258 (2015).

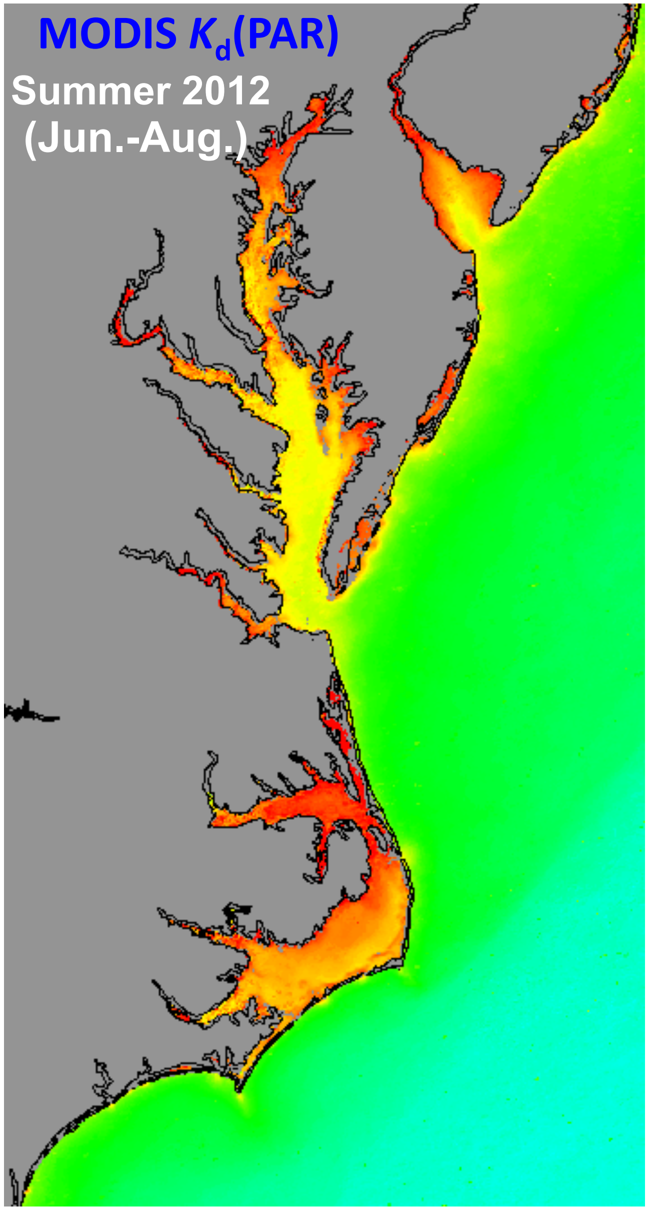
Validation results are well documented in the above two papers. Satellite-derived K_d(490) data have been used in several papers to study ocean properties. In particular, K_d(490) data over coastal and inland waters are significantly improved.

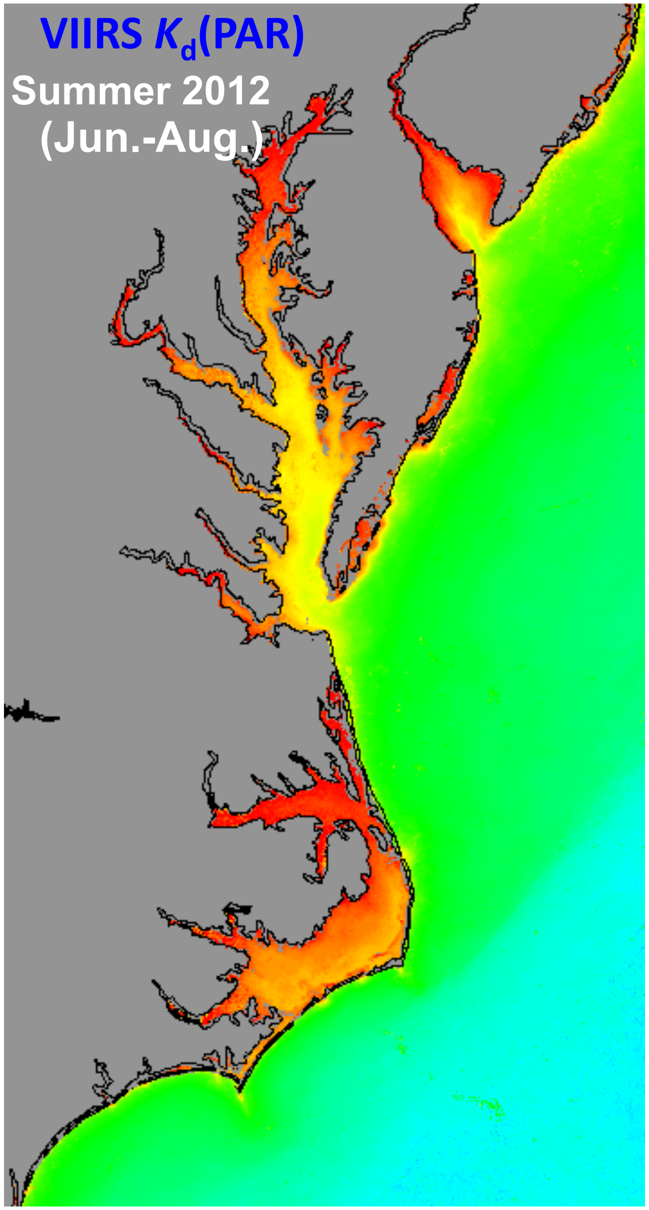
K_d(PAR) Validation Results



Seasonal Composites of MODIS-Aqua and VIIRS K_d(PAR)

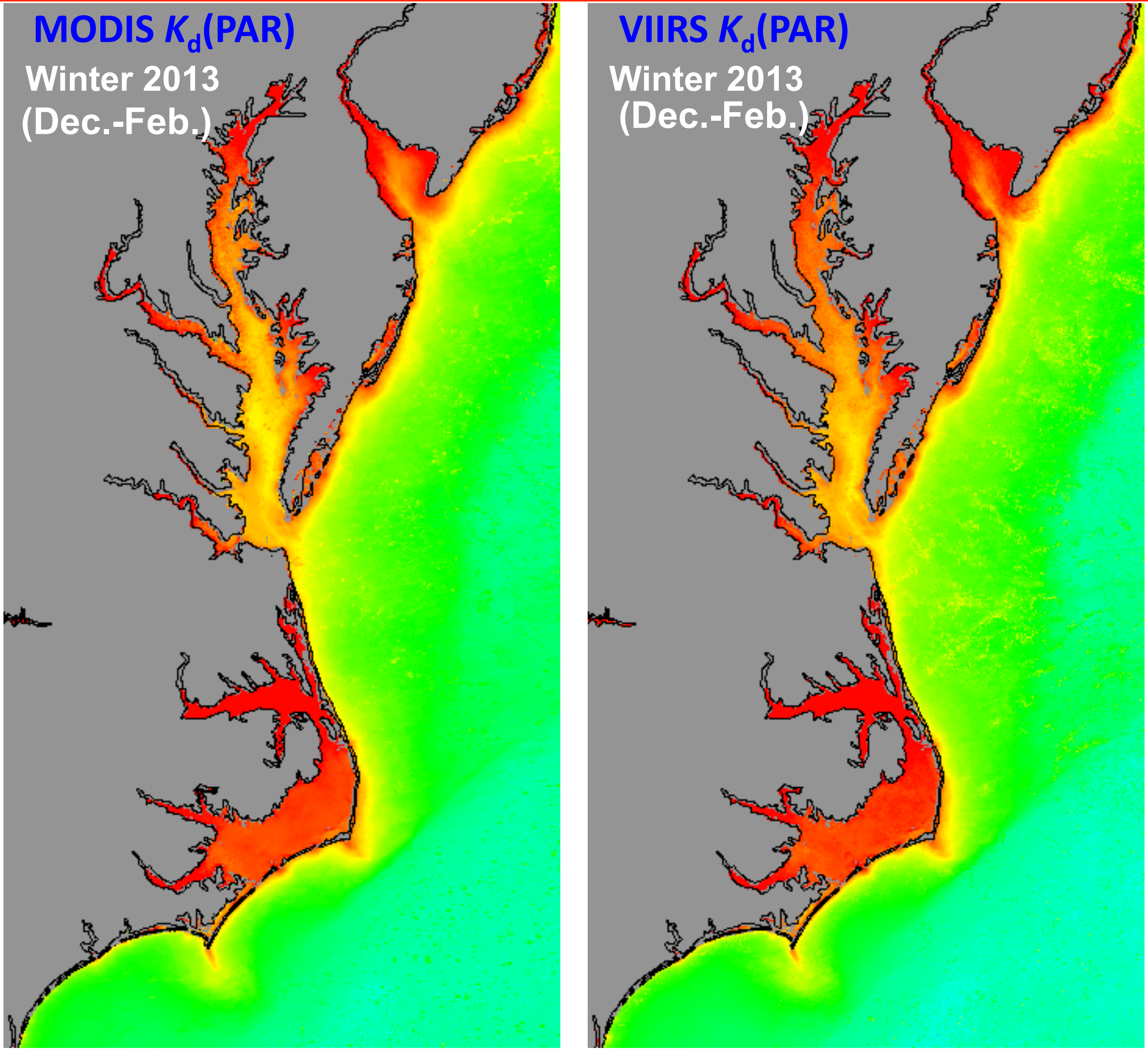
US East Coastal Region





Seasonal Composites of MODIS-Aqua and VIIRS K_d(PAR)

US East Coastal Region

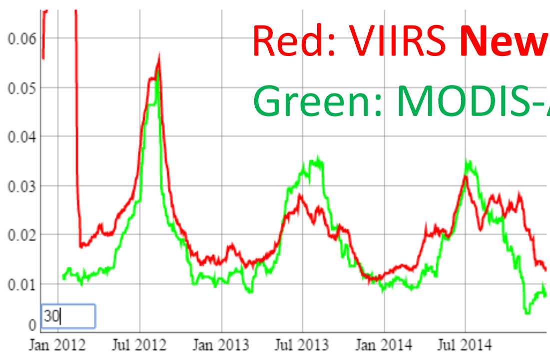


Comparison with MODIS (South Pacific Gyre)

Red: VIIRS **New EDR**

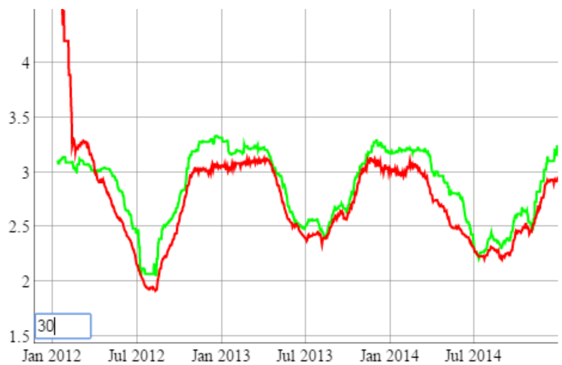
Green: MODIS-Aqua

Chl-a



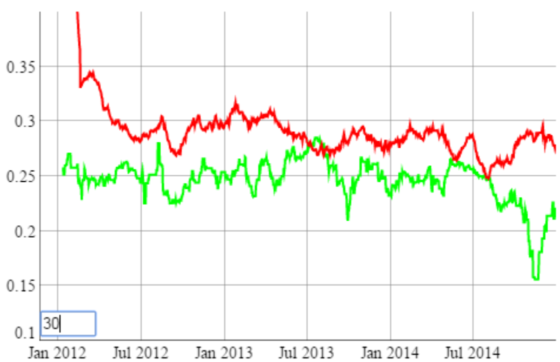
nLw(410)

nLw(443)

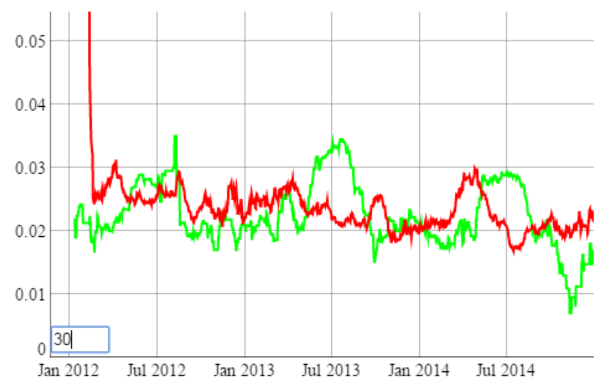


nLw(486)

nLw(551)

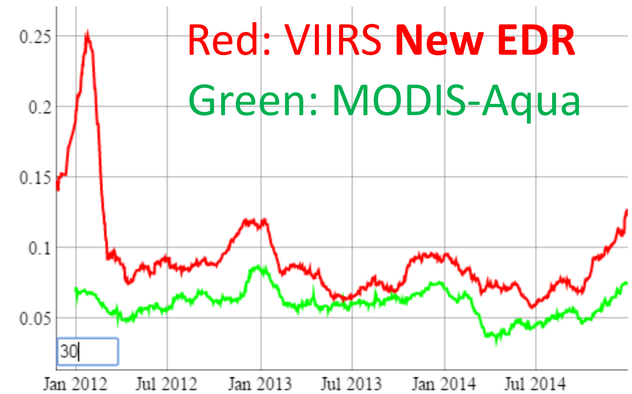


nLw(671)



Comparison with MODIS-Aqua (Hawaii)

Chl-a

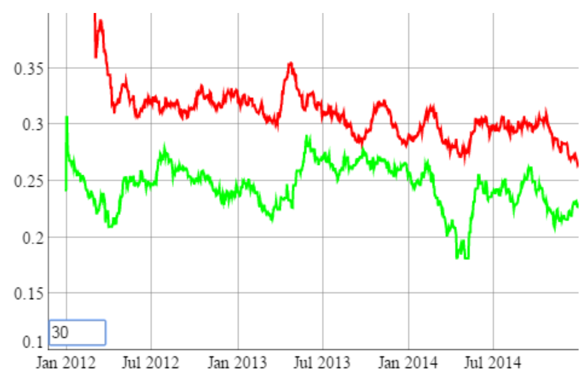


nLw(410)

nLw(443)

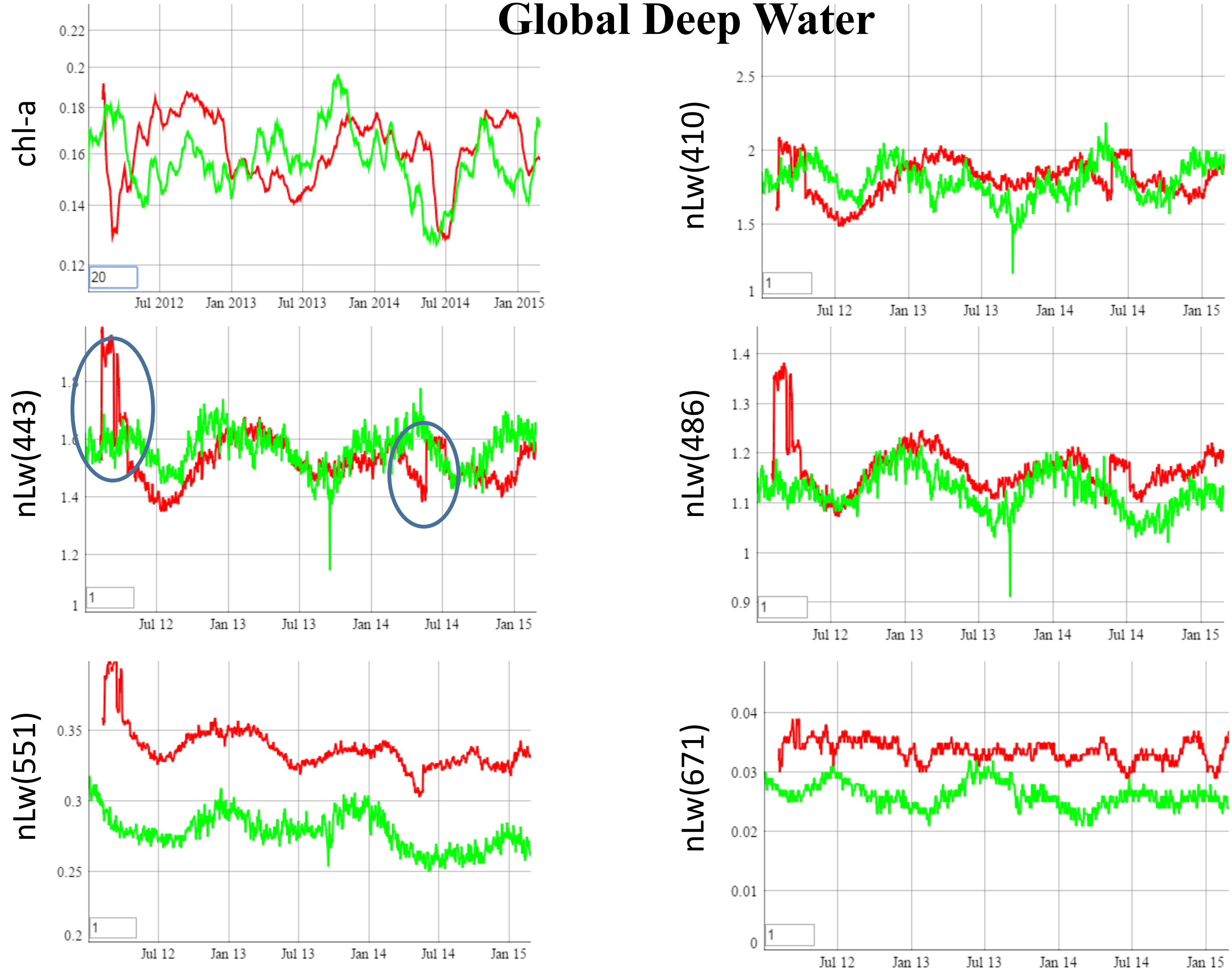
nLw(486)

nLw(551)



nLw(671)

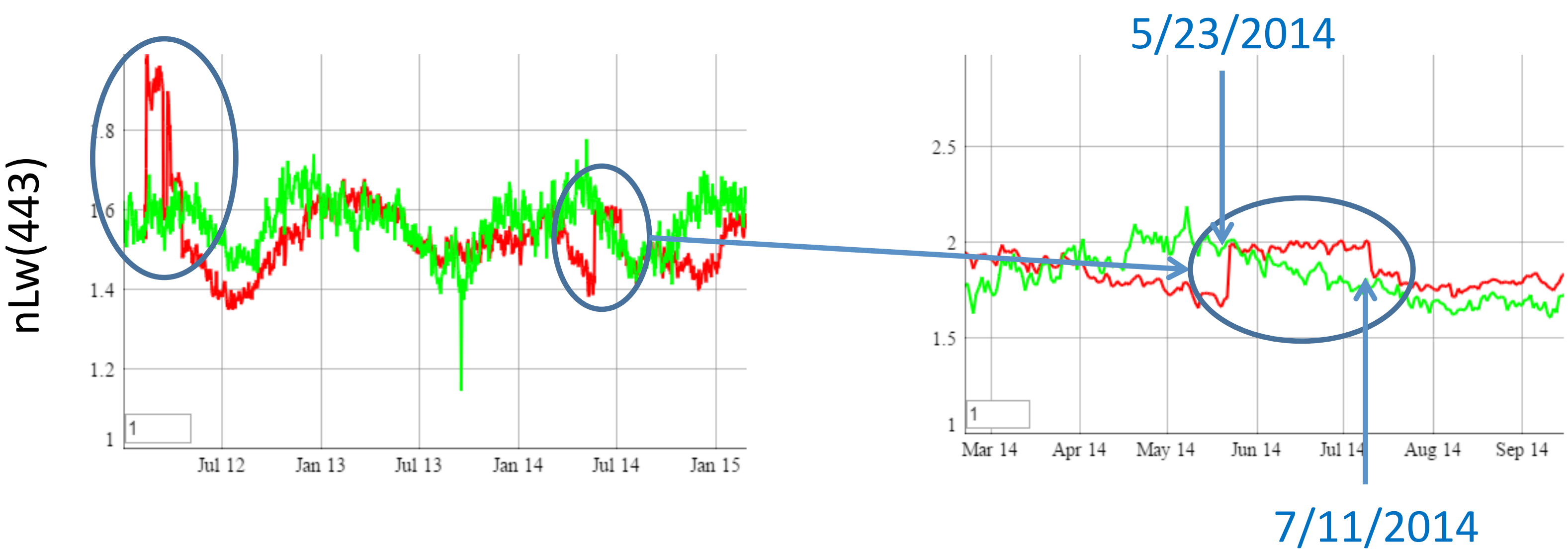
Global Deep Water



Red: VIIRS **New EDR** Green: **MODIS-Aqua**

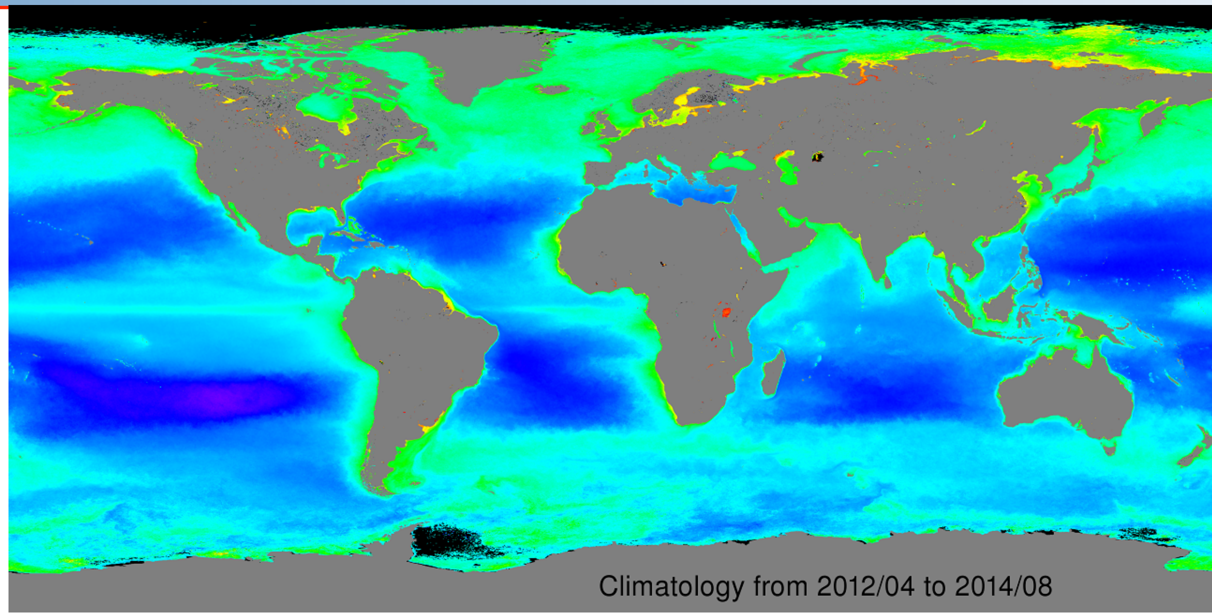
SDR Calibration Issues

Global Deep Water

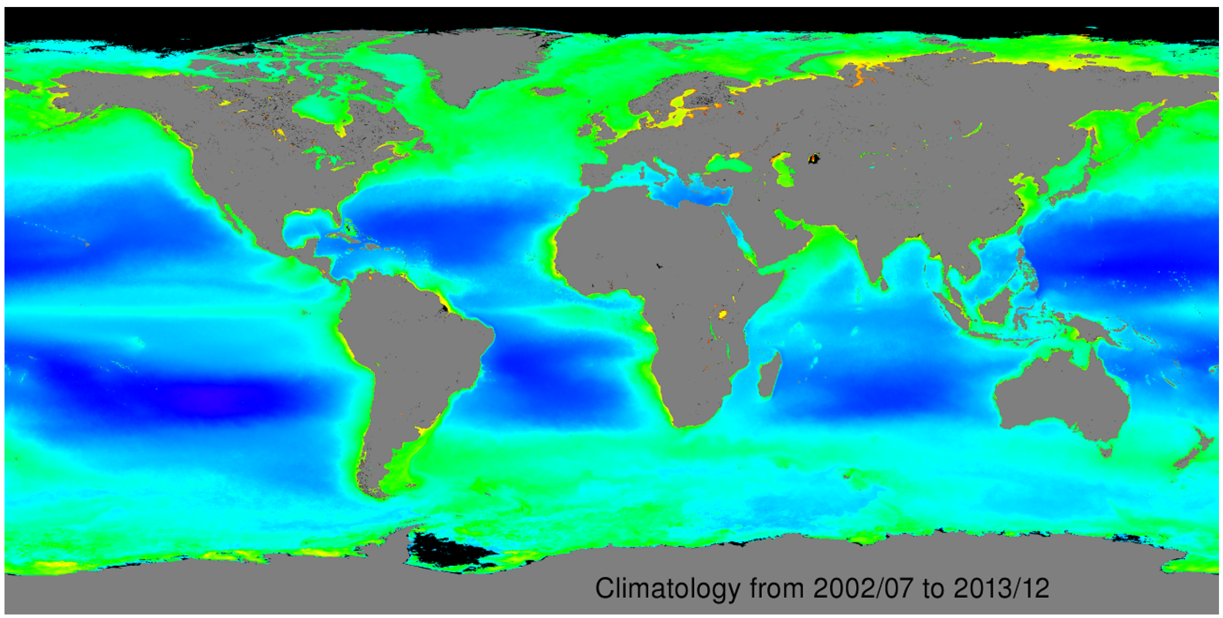


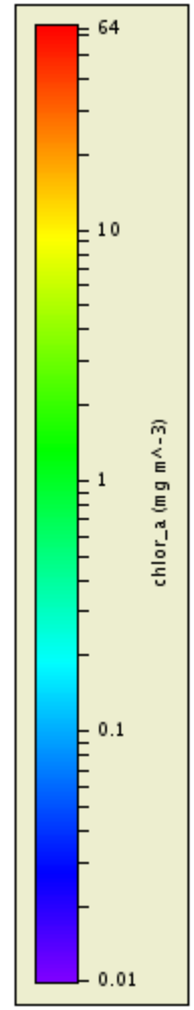
Global Chlorophyll-a Climatology

VIIRS



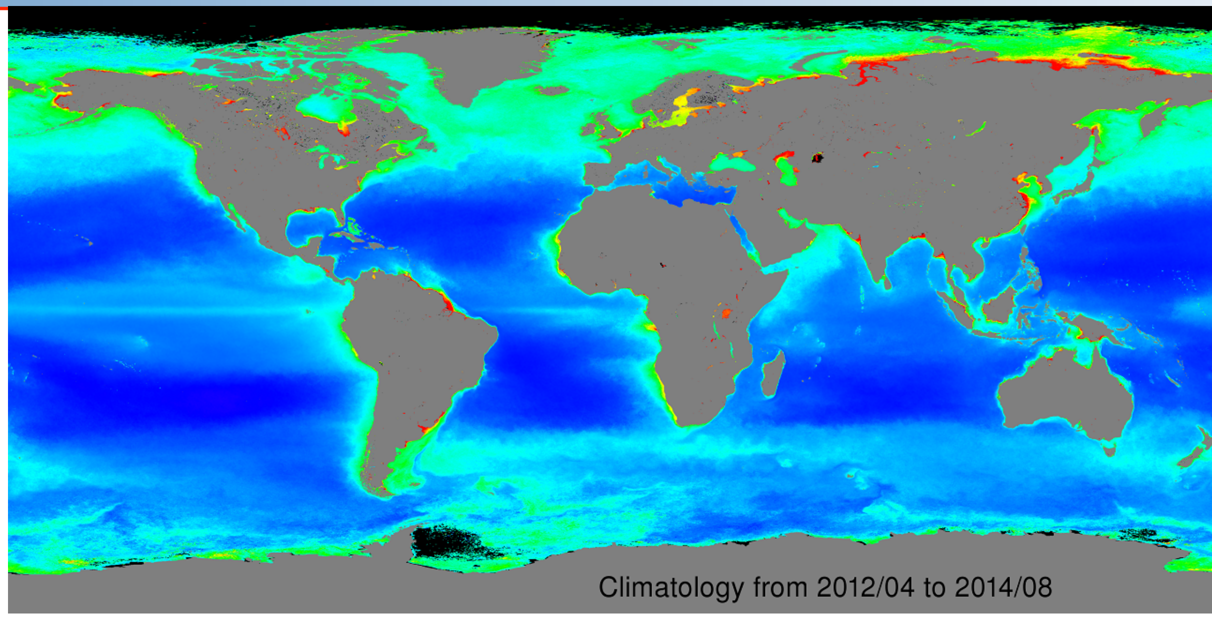
MODIS



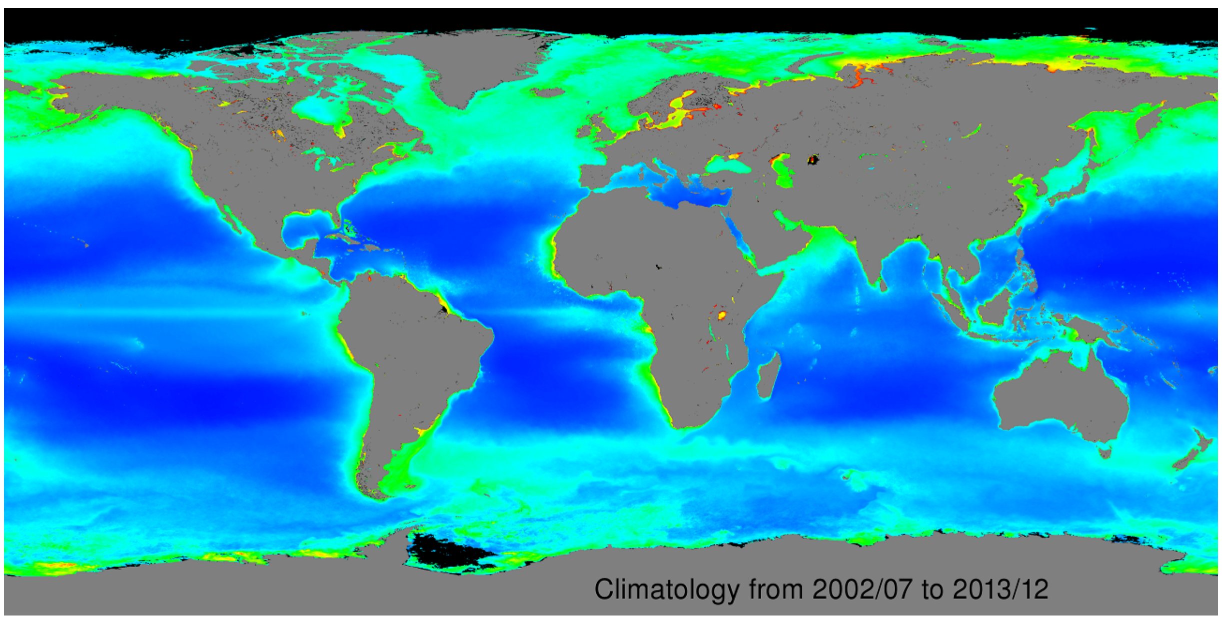


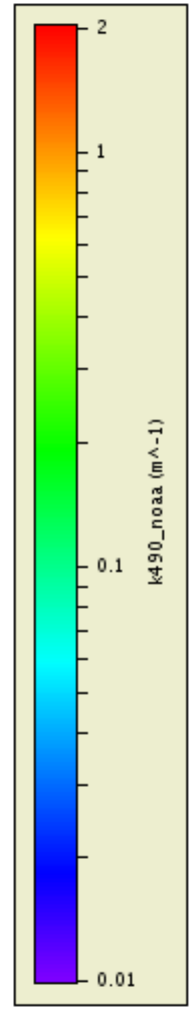
Global K_d(490) Climatology

VIIRS

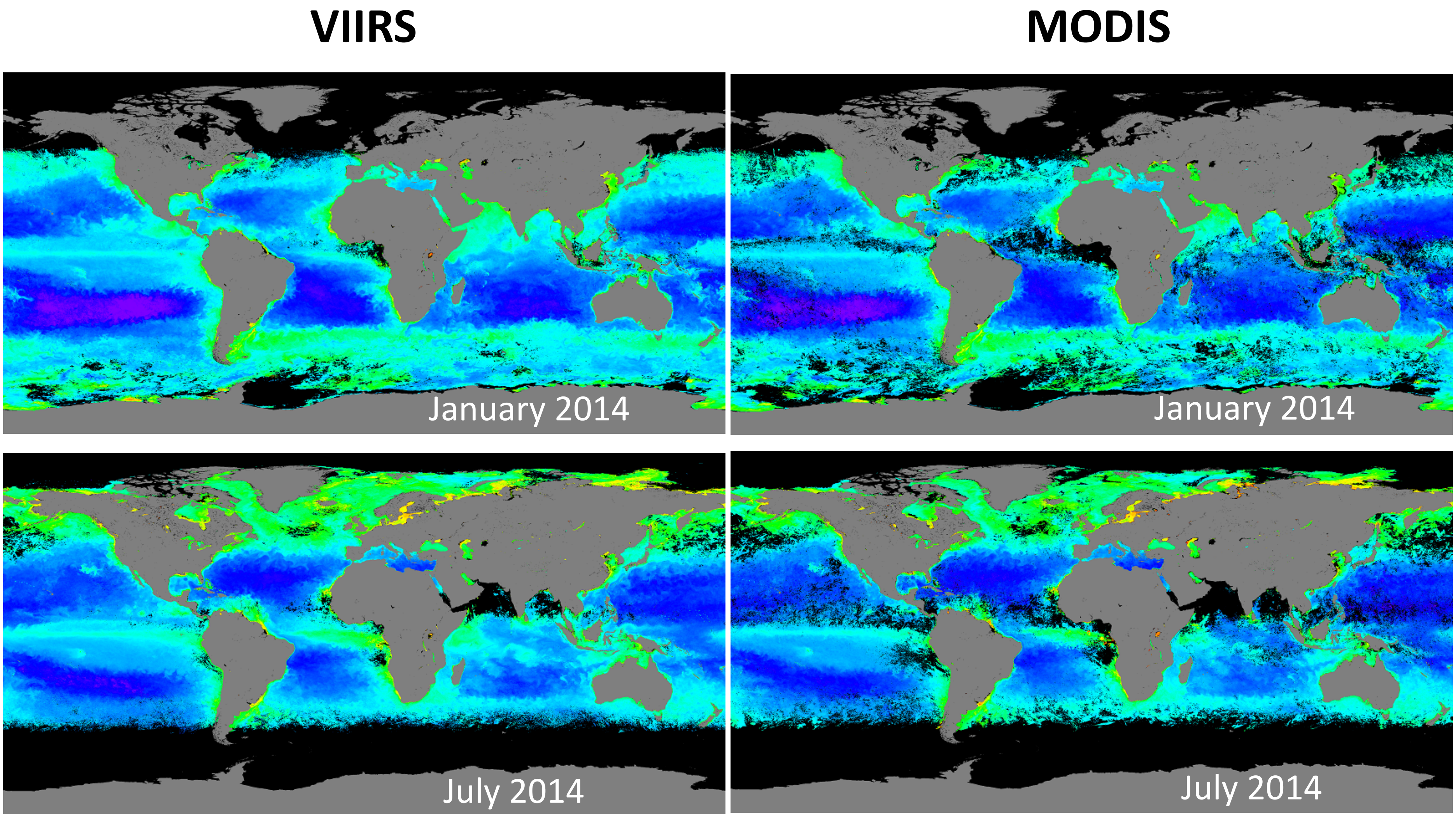


MODIS





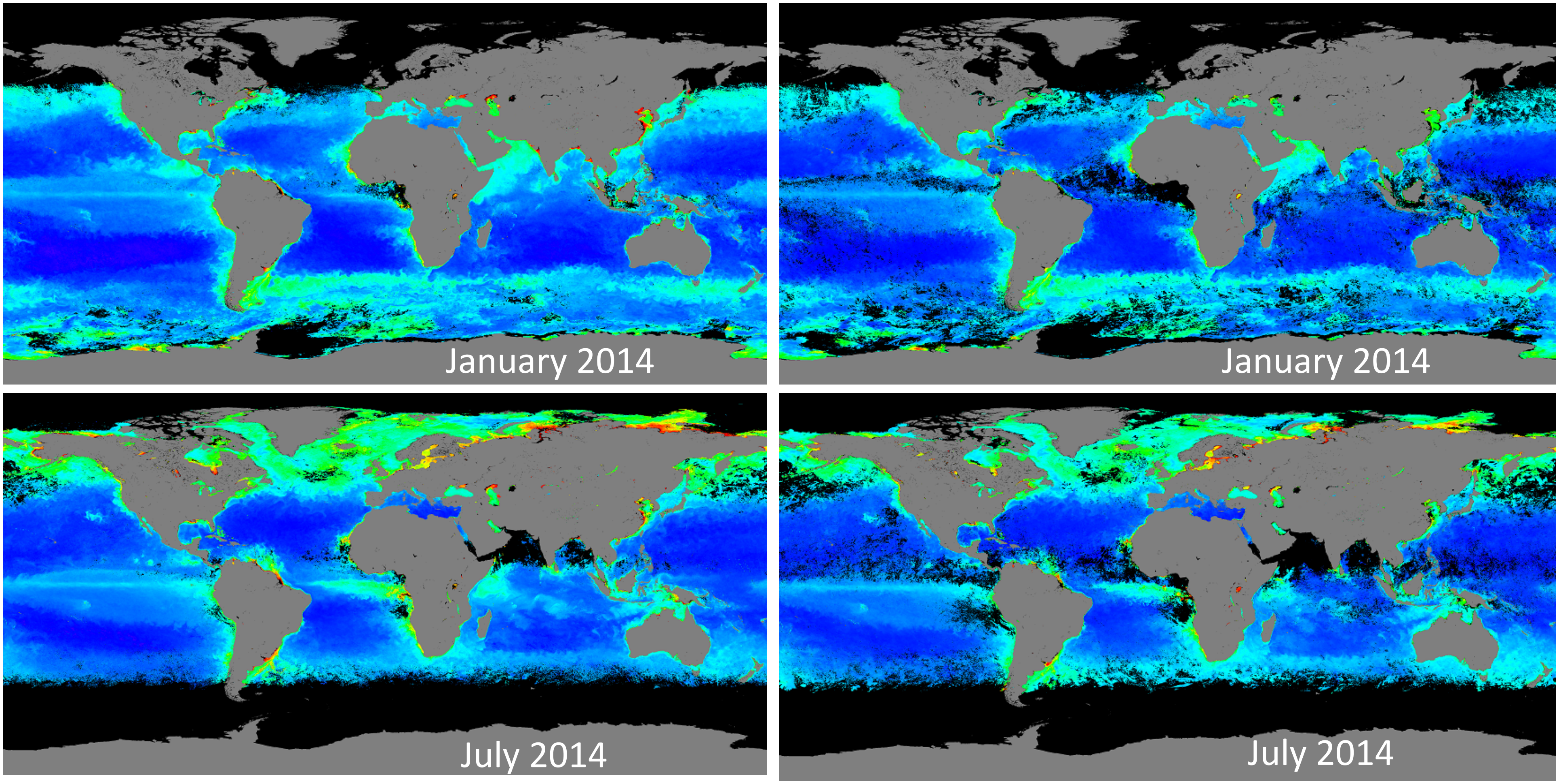
Global Image Comparisons: Chl-a



Similar spatial distributions/patterns, VIIRS has more **coverage**.

Global Image Comparisons: $K_d(490)$

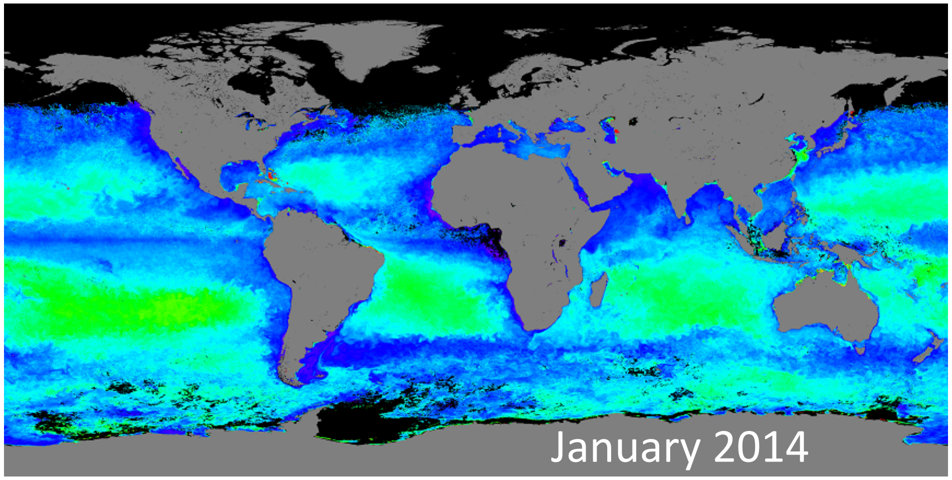
VIIRS **MODIS**

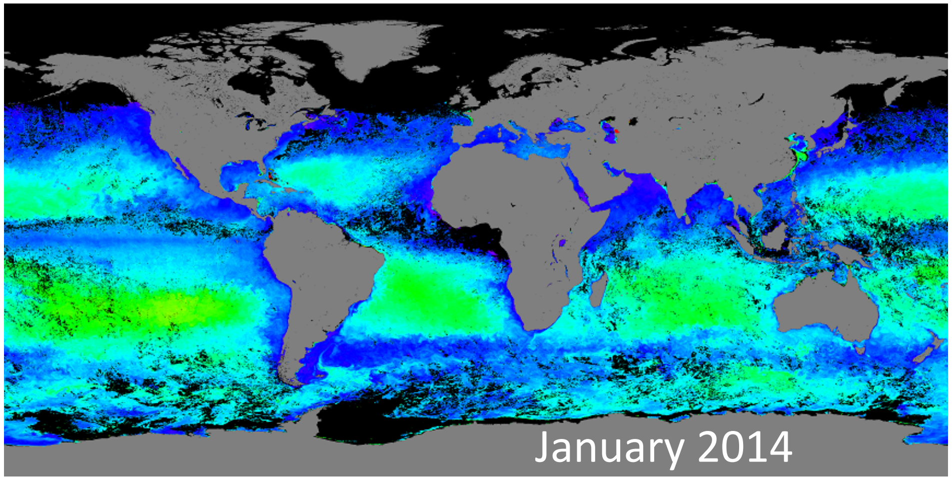


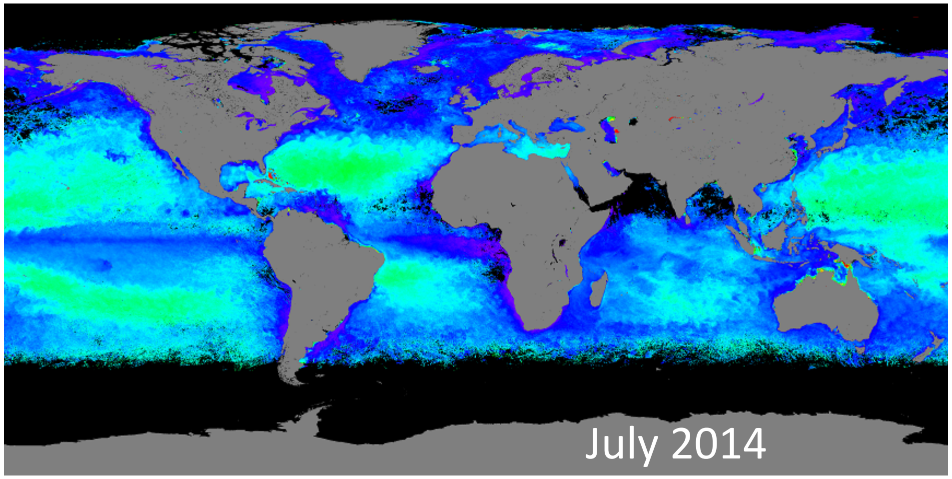
Similar spatial distributions/patterns, VIIRS has more **coverage**.

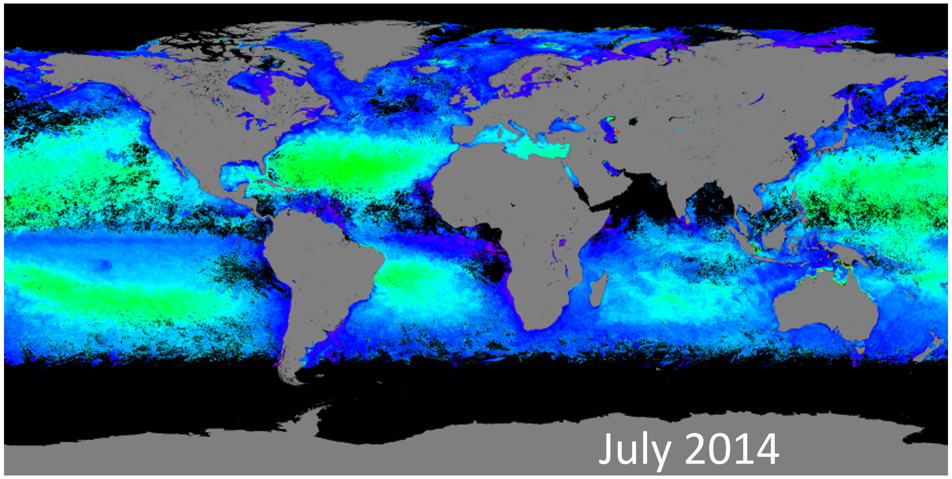
Global Image Comparisons: $nL_w(443)$

VIIRS **MODIS**



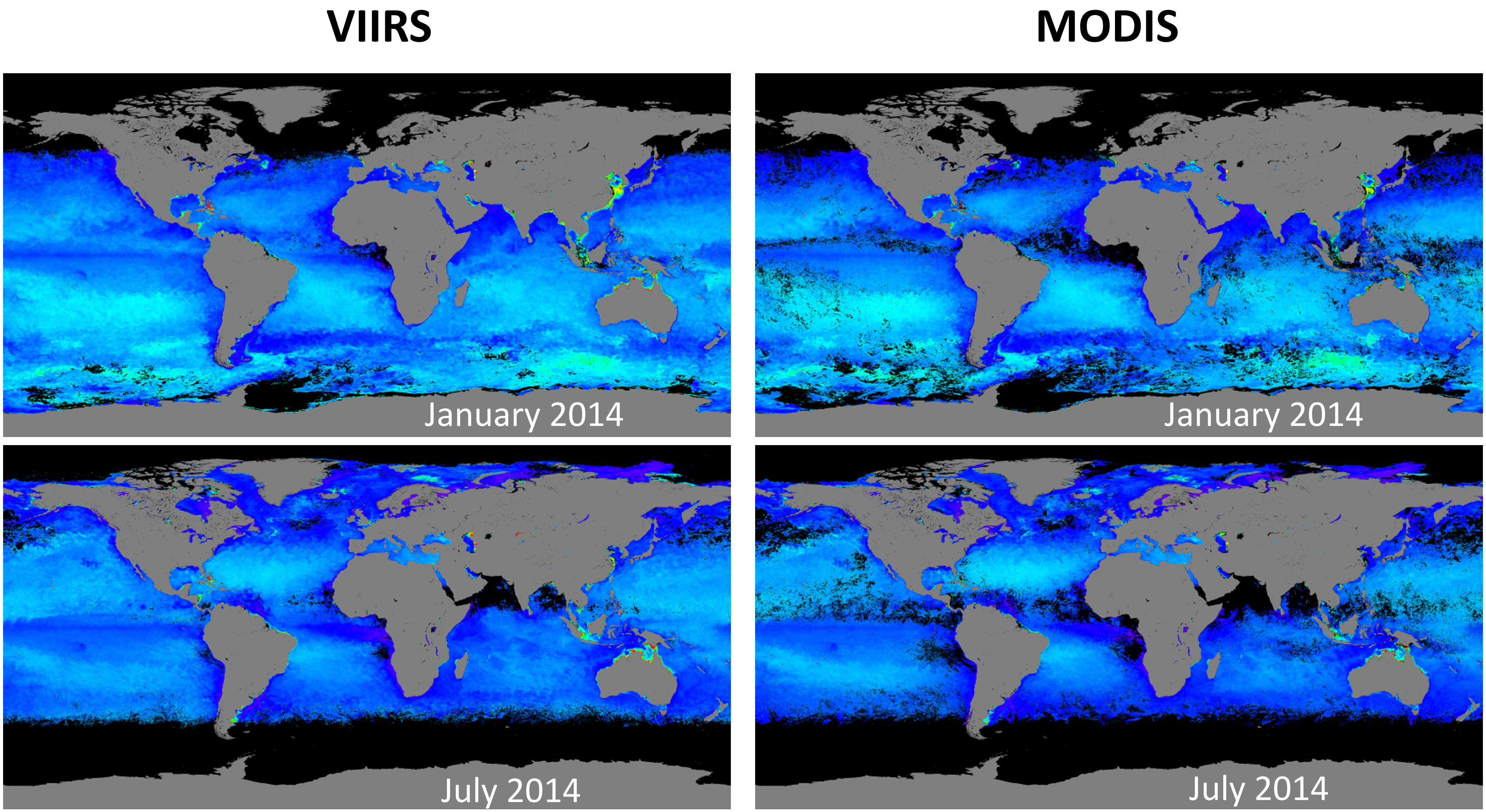






Similar spatial distributions/patterns, VIIRS has more **coverage**.

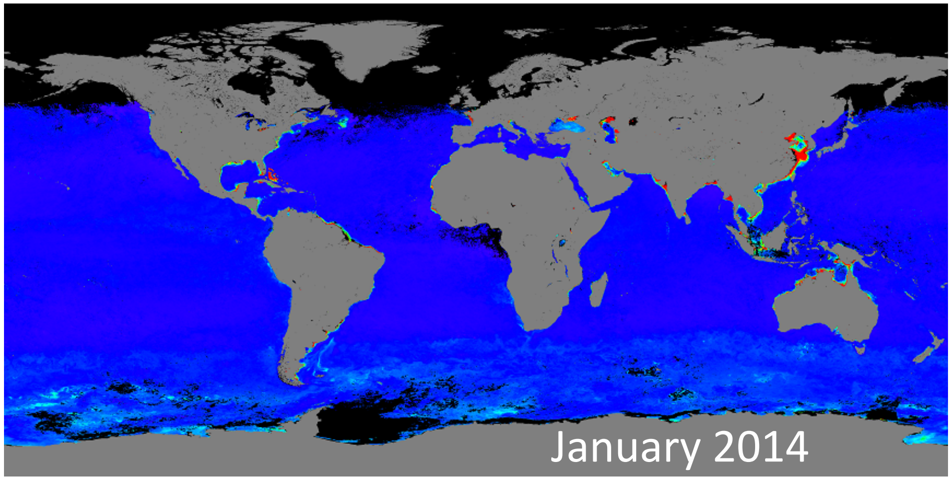
Global Image Comparisons: $nL_w(486)$

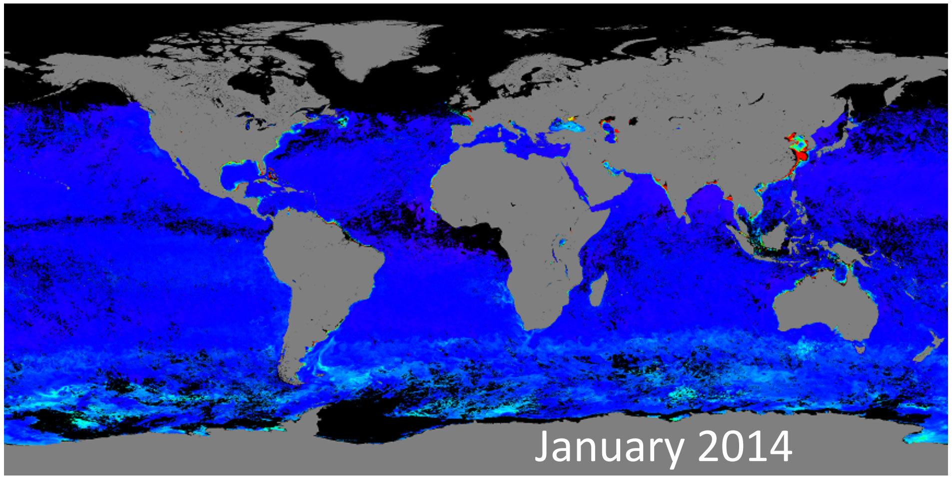


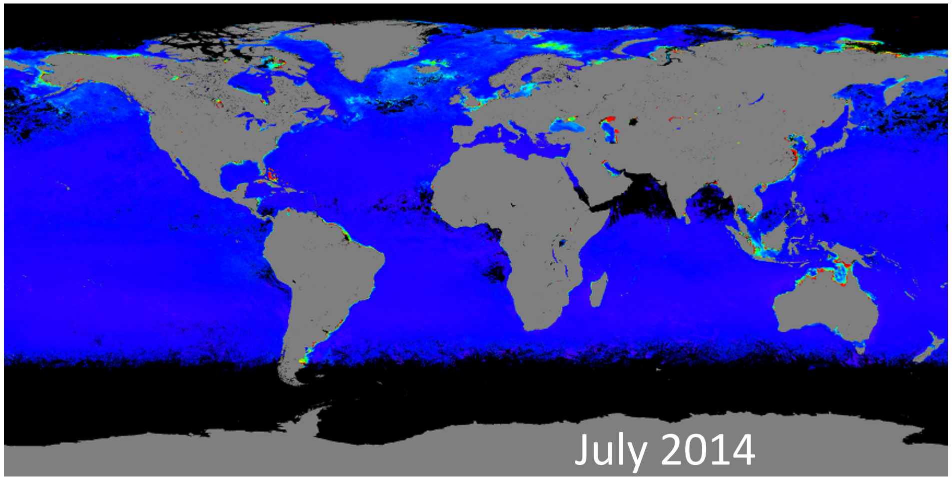
Similar spatial distributions/patterns, VIIRS has more **coverage**.

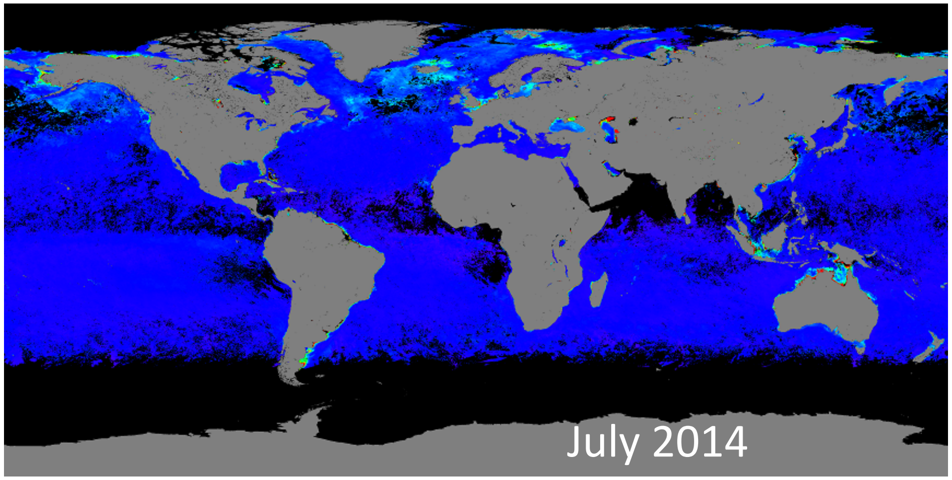
Global Image Comparisons: $nL_w(551)$

VIIRS | **MODIS**



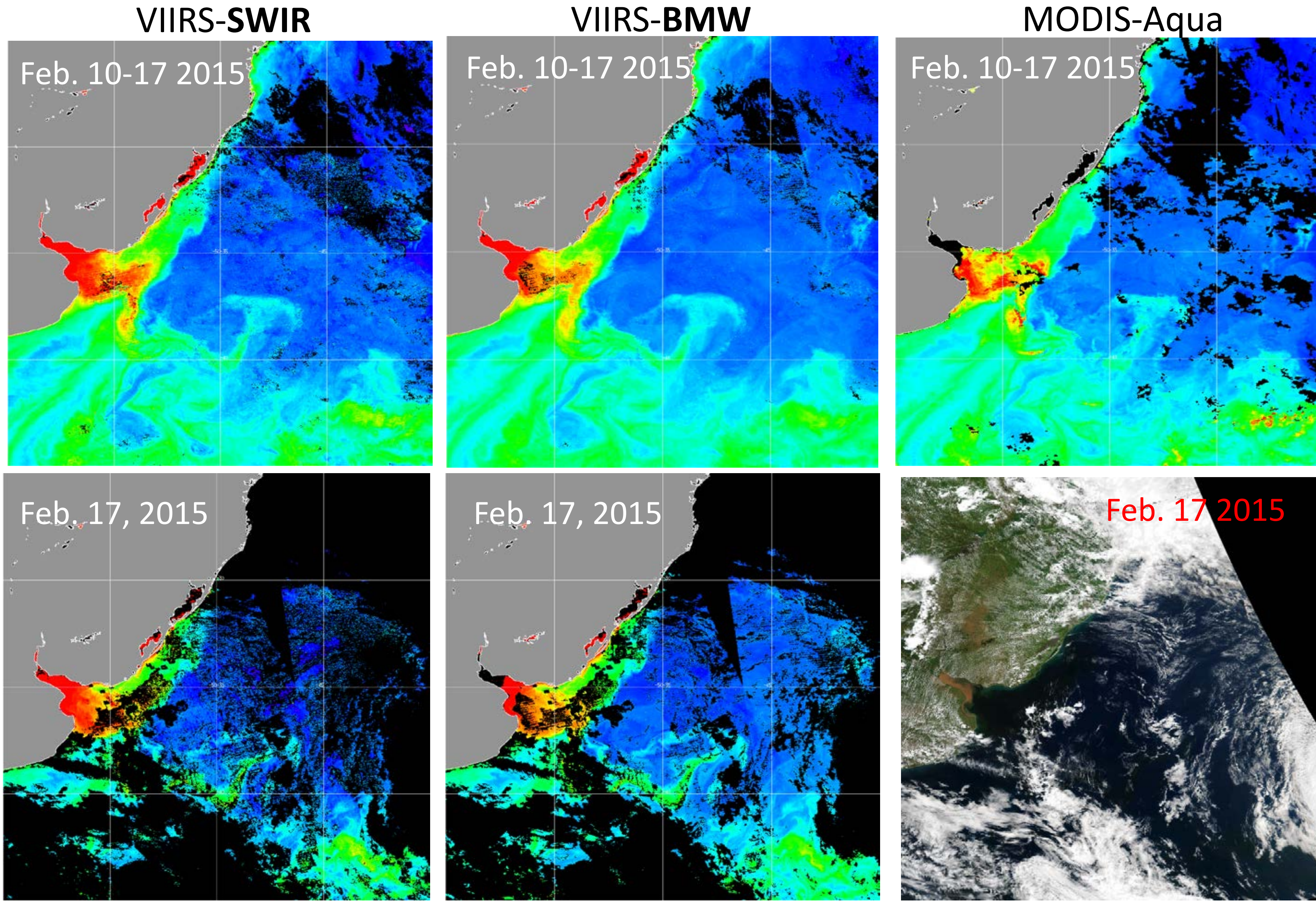






Similar spatial distributions/patterns, VIIRS has more **coverage**.

SWIR (K_d(490) - La Plata River)



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 (2015)

- MSL12 (2015) now is able to produce L2 file (EDR) in NetCDF4 format.
- 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.
- OCDAPS has also now been implemented with NetCDF4 L2 visualization capability.

NetCDF4: Metadata Examples

Global Attributes

```
:title = "VIIRSN Level-2 Data" ;
        :product_name = "V20150820200_test_L2.nc" ;
        :processing_version = "Unspecified" ;
        :history = "/data/data055/operational/lidej/bin/msl12_viirs_new par=/data/data097/lidej/worktmp/V20150820200.par" ;
        :instrument = "VIIRS" ;
        :platform = "Suomi-NPP" ;
        :Conventions = "CF-1.6" ;
        :Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
        :id = "L2/V20150820200_test_L2.nc" ;
        :date_created = "2015-03-26T16:28:36.000Z" ;
        :stdname_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convenention" ;
        :institution = "NOAA/NESDIS/STAR Satellite Oceanography and Climatology Division, Marine Ecosystems & Climate Branch" ;
        :creator_name = "NOAA/NESDIS/STAR/SOCD/MECB" ;
        :creator_url = "http://www.star.nesdis.noaa.gov/sod/mecb/color/" ;
        :processing_level = "L2" ;
        :cdm_data_type = "swath" ;
        :time_coverage_start = "2015-03-23T02:00:59.105Z" ;
        :time_coverage_end = "2015-03-23T02:02:22.731Z" ;
        :start_center_longitude = 178.2903f ;
        :start_center_latitude = -33.69938f ;
        :end_center_longitude = 176.9021f ;
        :end_center_latitude = -28.72484f ;
        :northernmost_latitude = -25.44588f ;
        :southernmost_latitude = -35.1025f ;
        :easternmost_longitude = -165.7507f ;
        :westernmost_longitude = 161.0155f ;
        :geospatial_lat_units = "degrees_north" ;
        :geospatial_lon_units = "degrees_east" ;
        :geospatial_lat_max = -25.44588f ;
        :geospatial_lat_min = -35.1025f ;
        :geospatial_lon_max = -165.7507f ;
        :geospatial_lon_min = 161.0155f ;
        :startDirection = "Ascending" ;
        :endDirection = "Ascending" ;
        :day_night_flag = "Day" ;
        :earth_sun_distance_correction = 1.00699079036713 ;
```

Variable Attributes

```
group: geophysical_data {
  variables:
      float chlor_a(number_of_lines, pixels_per_line) ;
          chlor_a:long_name = "Chlorophyll Concentration, Default Algorithm" ;
          chlor_a:units = "mg m^-3" ;
          chlor_a:_FillValue = -999.f ;
      short k490_noaa(number_of_lines, pixels_per_line) ;
          k490_noaa:long_name = "NOAA Diffuse attenuation coefficient at 490 nm" ;
          k490_noaa:scale_factor = 0.0002f ;
          k490_noaa:add_offset = 0.f ;
          k490_noaa:units = "m^-1" ;
          k490_noaa:_FillValue = -32768s ;
      short kpar_noaa(number_of_lines, pixels_per_line) ;
          kpar_noaa:long_name = "NOAA Diffuse attenuation coefficient for PAR" ;
          kpar_noaa:scale_factor = 0.0002f ;
          kpar_noaa:add_offset = 0.f ;
          kpar_noaa:units = "m^-1" ;
          kpar_noaa:_FillValue = -32768s ;
      short nLw_412(number_of_lines, pixels_per_line) ;
          nLw_412:long_name = "Normalized water-leaving radiance at 412 nm" ;
          nLw_412:scale_factor = 0.001f ;
          nLw_412:add_offset = 0.f ;
          nLw_412:units = "mW cm^-2 um^-1 sr^-1" ;
          nLw_412:_FillValue = -32768s ;
          nLw_412:solar_irradiance = 170.8f ;
```

Documentation

- Wang, M. and X. Liu, "MODIS Ocean Color Products Using the SWIR Method," *MODIS-SWIR Algorithm Theoretical Basis Document*, NOAA Product System Development and Implementation (PSDI), 40 pp., February 2012.
- Gordon, H. R. and M. Wang, "Retrieval of water-leaving radiance and aerosol optical thickness over the oceans with SeaWiFS: A preliminary algorithm," *Appl. Opt.*, **33**, 443–452, 1994.
- Wang, M., "Remote sensing of the ocean contributions from ultraviolet to near-infrared using the shortwave infrared bands: simulations," *Appl. Opt.*, **46**, 1535–1547, 2007.
- Wang, M. and W. Shi, "The NIR-SWIR combined atmospheric correction approach for MODIS ocean color data processing," *Opt. Express*, **15**, 15722–15733, 2007.
- Wang, M., X. Liu, L. Tan, L. Jiang, S. Son, W. Shi, K. Rausch, and K. Voss, "Impacts of VIIRS SDR performance on ocean color products," *J. Geophys. Res. Atmos.*, **118**, 10,347–10,360, 2013.
- Wang, M., X. Liu, L. Jiang, S. Son, J. Sun, W. Shi, L. Tan, P. Naik, K. Mikelsons, X. Wang, and V. Lance, "Evaluation of VIIRS ocean color products," *Proc. SPIE* 9261, *Ocean Remote Sensing and Monitoring from Space,* 92610E (November 8, 2014).

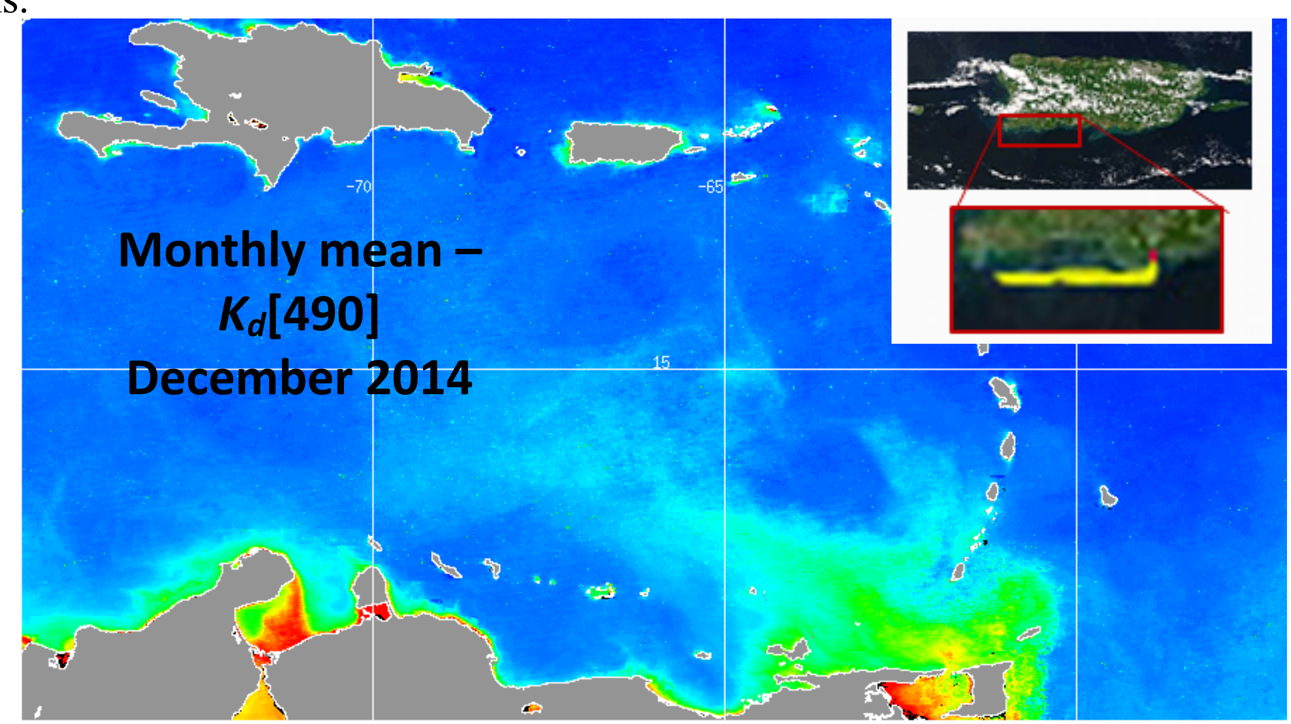
- ATBD will be updated for VIIRS.

Users & User Feedback #1 of 6

- **User list – NOAA Line Offices**
  - **NMFS**
    - Atlantic/Florida – represented by **Ron Vogel**
    - Pacific -- **Cara Wilson**
      - Surveys (NRT)
      - Long term model predictions
      - Students of Satellite Data analysis course
  - **NWS**
    - Ecosystem Forecasting - **Chris Brown**– getting OC into AWIPS; toward operational
    - EMC – Ocean modeling - **Avichal Mehra, Sudhir Nadiga**, **Eric Bayler**;
  - **NOS** – **Rick Stumpf**
    - HAB – Working to transition to VIIRS for operational forecasts
    - Sanctuaries
  - **OAR**
    - **Daniel Tong, Pius Lee**, Isoprene emissions
    - Ocean Acidification Program - **Dwight Gledhill**, proposed coastal salinity from OC a(443) and total alkalinity mapping.
  - **NESDIS** –
    - Ecosystem Forecasting - **Chris Brown**– getting OC into AWIPS; toward operational

Users & User Feedback #2 of 6

- **User list - cont'd**
  - **NOAA CoastWatch/OceanWatch**
    - Central –
      - Customizing VIIRS ocean color products for downstream users
      - Distribution portal for users
    - Northeast Node – **Ron Vogel, Howard Townsend** NOAA Chesapeake Bay Office – Chesapeake "Atlantis" ecosystem modeling – incorporating VIIRS observations.
  - **CoralReefWatch** – Puerto Rico project – **Al Strong, Robert Warner** – Light and temperature stress product (based on K_d(490)



Users & User Feedback #3 of 6

- **User list - cont'd**
  - **Outside NOAA**
    - **Igor Belkin - ** Univ. of Rhode Island
      - validating chlorophyll fronts
    - **Bob Arnone** – Univ. Southern Miss
      - (Stennis) research on uncertainties in
      - M4 and M5 bands

Summary Statistics: MOBY **n = 66**

Jan 2012 – May 2014, n = 66		M1	M2	M3	M4	M5
L2gen	Ratio avg (sat/insitu)	1.0138	1.0355	1.0304	1.0545	1.2990
	Ratio std	0.1327	0.1354	0.1304	0.2391	0.6644
	Median Ratio	1.0019	1.0205	1.0059	1.0120	1.1208
	Median Abs % chg	**8**	**8**	**9**	**14**	**26**
MSL12	Ratio avg (sat/insitu)	1.0507	1.0019	0.9784	1.0558	1.4411
	Ratio std	0.1346	0.1209	0.1090	0.1928	0.6469
	Median Ratio	1.0232	0.9759	0.9617	1.0048	1.2557
	Median Abs % chg	**9**	**9**	**8**	**11**	**40**

For reference point	412 nm	443 nm	490/488	555/547	670/667
SeaWifs med Abs%chg	6	6	7	11	50
MODIS med Abs%chg	6	7	6	13	36

- Very similar results with both processing techniques!
- Performance reasonable compared to SeaWifs &MODIS.
- Uncertainty increases with increasing wavelength

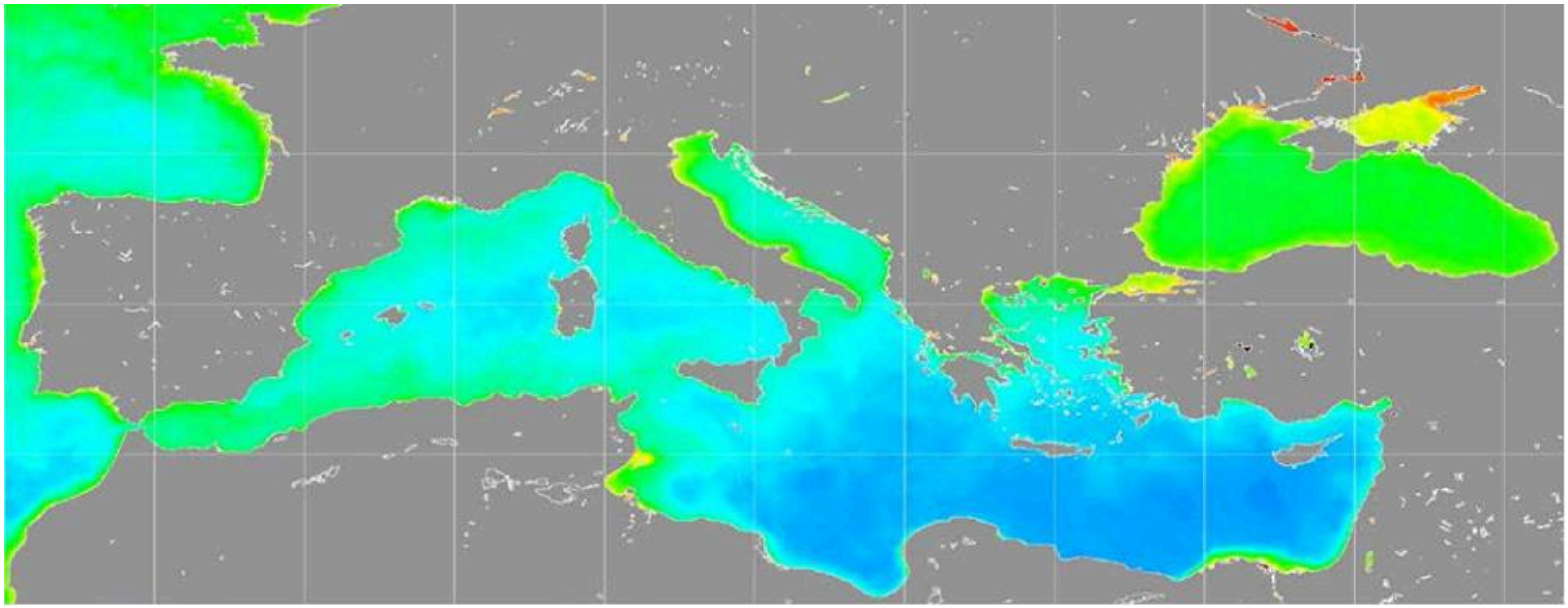
- How does this compare with green water/WCIS?

20

- **EUMETSAT** – Mediterranean Region; Copernicus Program (**Simon Elliot**) *Next page*

Users & User Feedback #4 of 6

- https://www.facebook.com/pages/Copernicus-EU/558113210871091



Copernicus EU
February 26

Here's one example of ocean colour products from NOAA's S-NPP spacecraft via EUMETSAT to MyOcean2, the consortium tasked by the European Commission to deliver the pre-operational Copernicus marine service. You see here four month composite images (October 2014 to January 2015) of Chlorophyll a concentration.

•Simon Elliott, EUMETSAT

Users & User Feedback #5 of 6

- Feedback from users
- **CoastWatch Quality Mitigation Project - Some User Interaction Highlights Presented at the December 2014 OCPOP Meeting**

NOAA/NWS/EMC (Global)

EMC GODAS/CFS: Are incorporating Chlorophyll a product into seasonal-to-interannual modeling.

EMC RTOFS: Are incorporating *Kd*(490) and *K*(par) products into near-real-time ocean modeling.

NOAA/NOS/NCOSS (GOMx)

Generally agreed that MSL12 was an improvement over IDPS for VIIRS

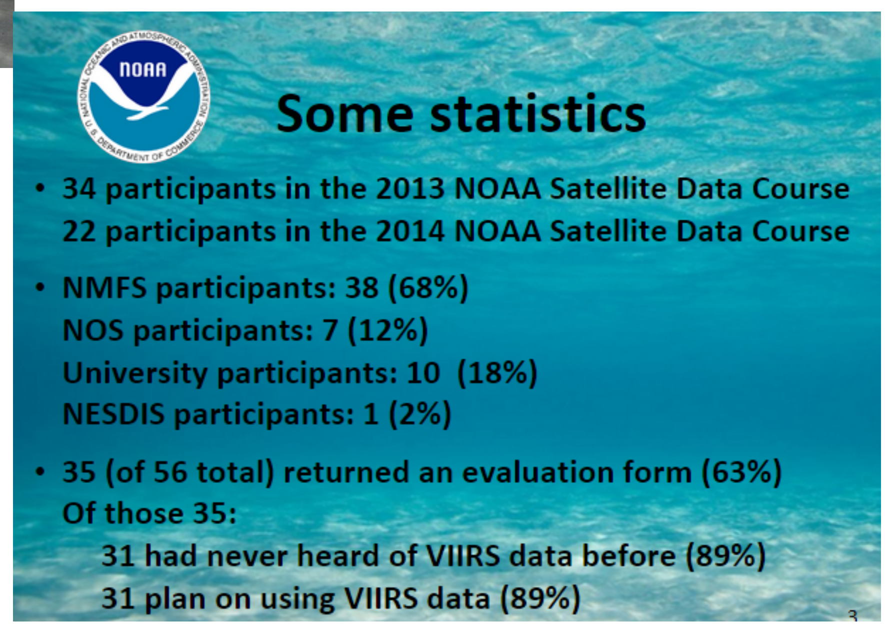
Noted that all ocean color algorithms still need improvements for coastal regions.

the VIIRS MSL12 data are useful for capturing blooms.

Users & User Feedback #6 of 6

Photo of 2013 participants of Cara Wilson's (NMFS/SWFSC) NOAA Satellite Data Training Course.
Student travel costs were supported by JPSS PGRR. Dozens of projects have benefitted from applying VIIRS ocean color data.

Some statistics presented by Dr. Wilson during the OCPOP meeting in December 2014



Ocean Color Tools for Reef Managers

http://coralreefwatch.noaa.gov/satellite/research/oceancolor.php

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

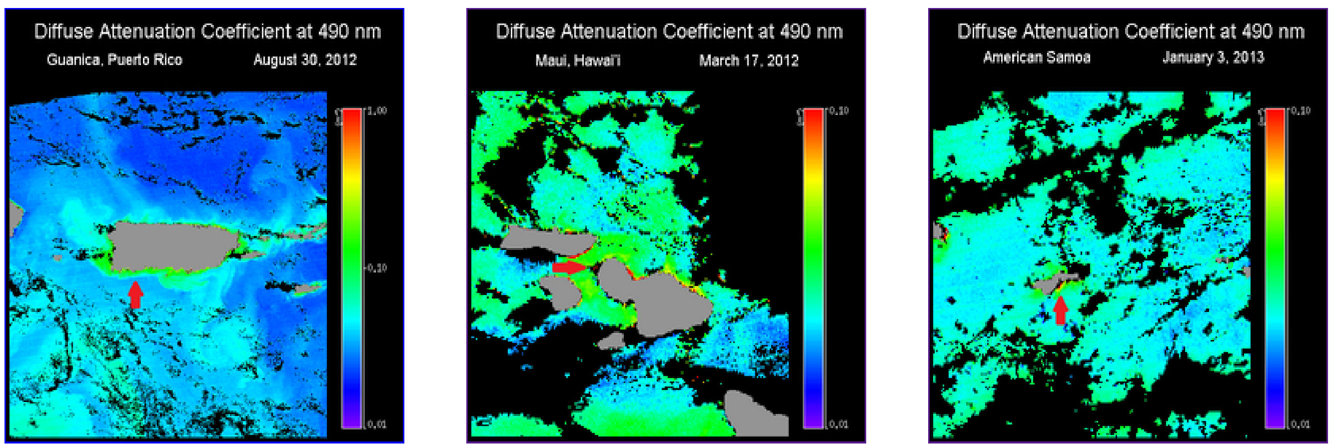
Coral Reef Watch

DOC > NOAA > NESDIS > STAR > CRW

CRTF | CRCP | CREIOS | CoRIS

- CRW Home
- Product Overview
- Near-Real-Time Data
- Experimental Products
- Research Activities
  - Ocean Color
  - Projections: OA/Bleaching
  - Ocean Acidification
  - Hydrodynamic Modeling
  - Paleoclimatology
  - High-resolution SST
  - Decision Support System
  - QCed Bleaching Obs
- Outreach/Education

Satellite Ocean Color Product Development



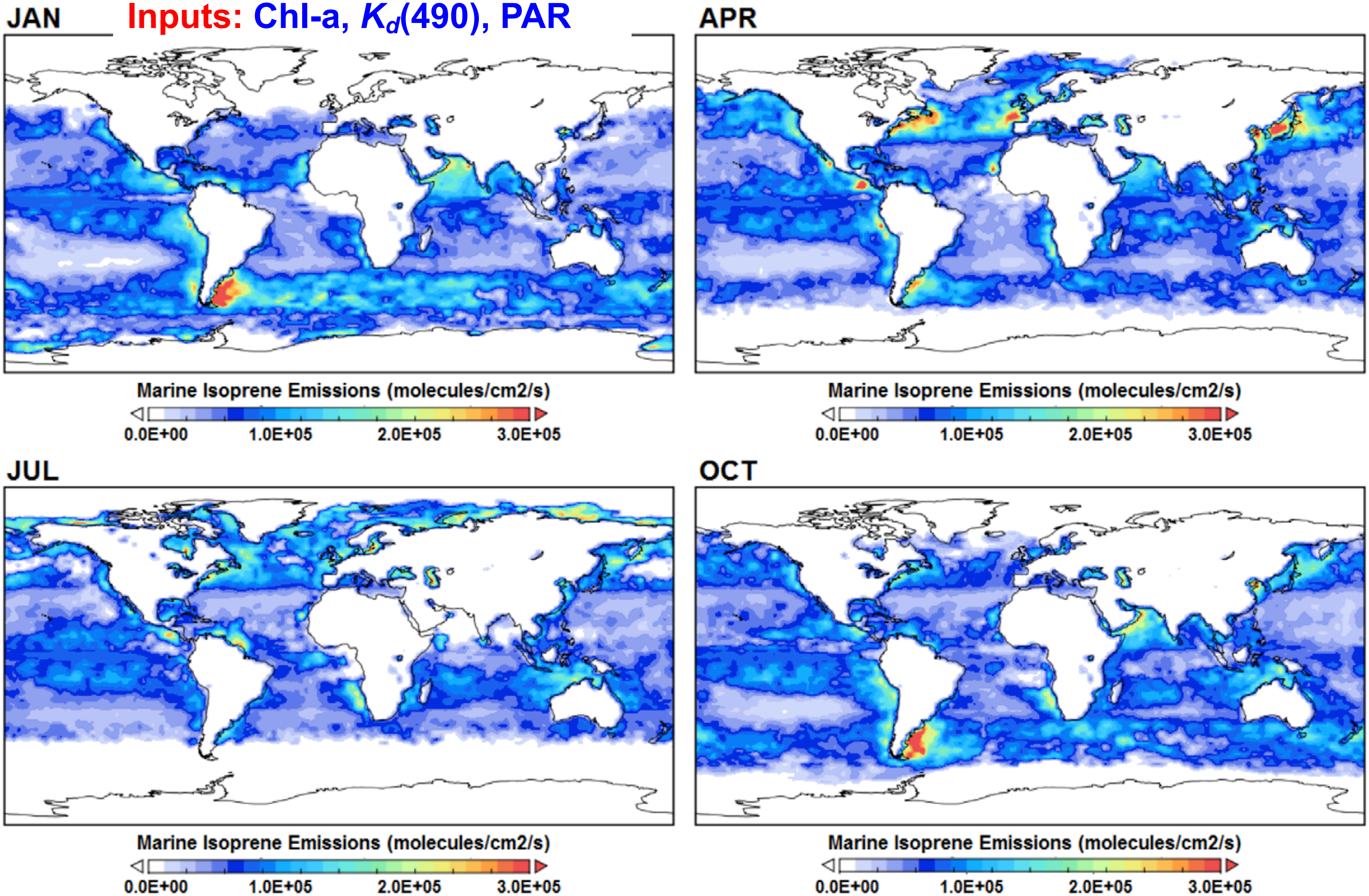
NOAA Coral Reef Watch and NOAA/NESDIS' Ocean Color Team are working closely with partners in the U.S. Coral Reef Task Force (USCRTF) Watershed Working Group (WWG) to develop pilot satellite ocean color products using data from the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the Suomi National Polar-orbiting Partnership (S-NPP) satellite operated by the NASA-NOAA Joint Polar Satellite System (JPSS).

From ***Coral Reef Watch***

Global Distribution of Marine Isoprene Emission

Tong et al. (JPSS Proving Ground Project)

Inputs: Chl-a, K_d(490), PAR



Going Forward (1): Two Data Streams for VIIRS Ocean Color EDR

To meet requirements from **All** users (operational, science research, modeling, etc.), we plan to produce VIIRS ocean color products in two data streams:

- **Near-Real-Time (NRT) Ocean Color Data Processing (12-24 hours):**
  - Quick turn around with ~12-24 hours latency (operational)
  - Using standard IDPS SDR data
  - Ancillary data using the Global Forecast System (GFS) model
  - Data may not be completed due to various issues (SDR missing, computer, etc.)
  - Data will be processed in NOAA CoastWatch and OSPO
- **Science Quality Ocean Color Data Processing (One week delay):**
  - About one-week delay
  - Reprocessed mission-long ocean color data and continue-forward data stream
  - Using improved SDR (based on IDPS SDR data)
  - Science quality (assimilated) NCEP ancillary data
  - Complete global coverage
  - May expand to more experimental products & test with improved algorithms
  - Ocean color EDR will be reprocessed (mission-long) about every two-three years (or as needed, e.g., short-term data reprocessing, error fixing, etc.)
  - Data will be processed in NOAA/STAR and transferred to CoastWatch

Going Forward (2): Future Plans

- Complete VIIRS mission-long ocean color data reprocessing (science quality, i.e., improved SDR, algorithms, and science quality ancillary data).
- VIIRS reprocessed data stream will go forward (about one-week delay). VIIRS science quality data will be distributed through CoastWatch and other means (e.g., NODC effort).
- Cal/Val team will finish the 2014 VIIRS dedicated cruise report and in situ data analyses (e.g., improve in situ data quality).
- More in situ data are needed (2015): April (Lee/Arnone), May (Hu), June-July (Ondrusek), NRL in AERONET-CSI site, etc.
- In situ data quality (instrument calibration, measurement protocols, data processing methodology, etc.)
- Dedicated VIIRS ocean color Cal/Val cruise in October 2015, and establishing annual Cal/Val cruises.
- Continue work on sensor on-orbit calibration, algorithms improvements, etc.
- We have been working on J1 instrument. Need more efforts for J1 VIIRS pre-launch data analyses as J1 close to launch (access to J1 sensor data).
- Algorithms improvements for both open oceans and coastal/inland waters. In particular, significant efforts are needed for coastal/inland waters.

Conclusions

- VIIRS ocean color products have been significantly improved after the implementations of some updates, new algorithms and with vicarious calibration using relatively long MOBY in situ data.
- With users requests, two new ocean color products (K_d(490) and K_d(PAR)) are added to the standard product list. Several new products are also included as experimental products.
- Reprocessed/improved SDR further improves VIIRS ocean color EDR, and provide more stable/ consistent science quality ocean color data.
- To meet ALL users requirements, two data streams will be produced: near-real-time (quick turn around) and one-week delayed science quality data.
- We have extensively evaluated MSL12-produced VIIRS ocean color data (three data streams) using all possible in situ data (MOBY, AERONET-OC, NOAA OC Cal/Val team dataset, NASA SeaBASS, etc.) and also compared with those from MODIS-Aqua.
- In general, over open oceans VIIRS OC normalize water-leaving radiance spectra (M1-M5) and Chl-a show good agreements with in situ data and meet the requirements. In addition, K_d(490) and K_d(PAR) show good accuracy for both open oceans and coastal waters.
- However, over coastal regions, although there are some excellent agreements between VIIRS and in situ data, there are also some notable differences in VIIRS-derived ocean color data compared with in situ data. Significant research efforts are still needed (as OC teams & the community).
- Significant efforts for VIIRS on-orbit calibration is needed in order to meet ocean color requirements, as well as vicarious calibrations using MOBY data.
- We have successfully completed NOAA dedicated Cal/Val cruise, and plan to have it in Oct. 2015. Significant efforts for in situ data collection is needed for validating VIIRS ocean color products.
- Based on the definition and the evidence shown in the presentation (demonstrated performance, documentation, sufficient analyses, ready for operational, forward plans), VIIRS ocean color EDR has met the validation stage, and is ready for operational use. It should be noted that further improvement in both SDR and EDR are needed, particularly for coastal/inland waters.

VIIRS Ocean Color EDR Team Publications (2014)

(Peer-reviewed)

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Sun, J. and M. Wang, "On-orbit characterization of the VIIRS solar diffuser and solar diffuser screen," *Appl. Opt.*, **54**, 236–252, 2015.

Sun, J. and M. Wang, "Visible Infrared Imaging Radiometer Suite solar diffuser calibration and its challenges using solar diffuser stability monitor", Appl. Opt., 53, 8571-8584 (2014). doi:10.1364/AO.53.008571

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Hlaing, S., A. Gilerson, R. Foster, M. Wang, R. Arnone, and S. Ahmed, "Radiometric calibration of ocean color satellite sensors using AERONET-OC data", Opt. Express, 22, 23385-23401 (2014). doi:10.1364/OE.22.023385

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Sun, J., X. Xiong, A. Angal, H. Chen, A. Wu, and X. Geng, "Time-Dependent Response Versus Scan Angle for MODIS Reflective Solar Bands", IEEE Trans. Geosci. Remote Sensing, 52, 3159-6507 (2014). doi:10.1109/TGRS.2013.2296747

Doxaran, D., N. Lamquin, Y. J. Park, C. Mazeran, J. H. Ryu, M. Wang, and A. Poteau, "Retrieval of the seawater reflectance for suspended solids monitoring in the East China Sea using MODIS, MERIS and GOCI satellite data", Remote Sens. Environ., 146, 36-48 (2014). doi:10.1016/j.rse.2013.06.020

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Sun, J., X. Xiong, S. Madhavan, and B. N. Wenny, "Terra MODIS band 27 electronic crosstalk effect and its removal", IEEE Trans. Geosci. Remote Sensing, 52, 1551-1561 (2014). doi:10.1109/TGRS.2013.2252180

There are many conference papers, presentations/talks related to VIIRS ocean color EDR in various meetings and workshops etc.

For full list, visit: **http://www.star.nesdis.noaa.gov/sod/mecb/color/**

Questions?