Satellite Ocean Color Remote Sensing: Current Status of VIIRS Ocean Color Products and Some Applications

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& NOAA Ocean Color Team

NOAA/NESDIS/STAR

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Satellite Science Week, February 23-27, 2015

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

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

Ocean Color Spectra


Lake Taihu


Chesapeake Bay

VIIRS Ocean Color Cal/Val Team 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 DR- Software updates
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 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

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.

Satellite-Measured Ocean Color Products

➢ Ocean Color Products:

- **Normalized Water-leaving Radiance $nL_w(\lambda)$** in mW cm^{-2} μm^{-1} sr^{-1}.
- **Chlorophyll-a** Concentration (Chl-a) in mg m^{-3}.
- Water **Diffuse Attenuation Coefficient** at 490 nm **K_d(490)** in m^{-1}, which is related to light penetration and availability in aquatic systems.
- Water Diffuse Attenuation Coefficient for Photosynthetically Available Radiation (PAR) **K_d(PAR)** in m^{-1}.
- Inherent Optical Properties (**IOPs**) (using QAA).
- Photosynthetically Available Radiation (PAR).
- Others, e.g., **Total Suspended Sediment** (TSS) in mg l^{-1}, water **Turbidity** in NTU, etc.

➢ Ocean biological and biogeochemical properties, e.g., Chl-a, K_d(490), K_d(PAR), TSS, Turbidity, etc., are derived from satellite-measured $nL_w(\lambda)$ spectra.

➢ Ocean color data processing:

- NOAA Multi-Sensor Level-1 to Level-2 (NOAA-**MSL12**), which is now NOAA VIIRS **official ocean color data processing system**.

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

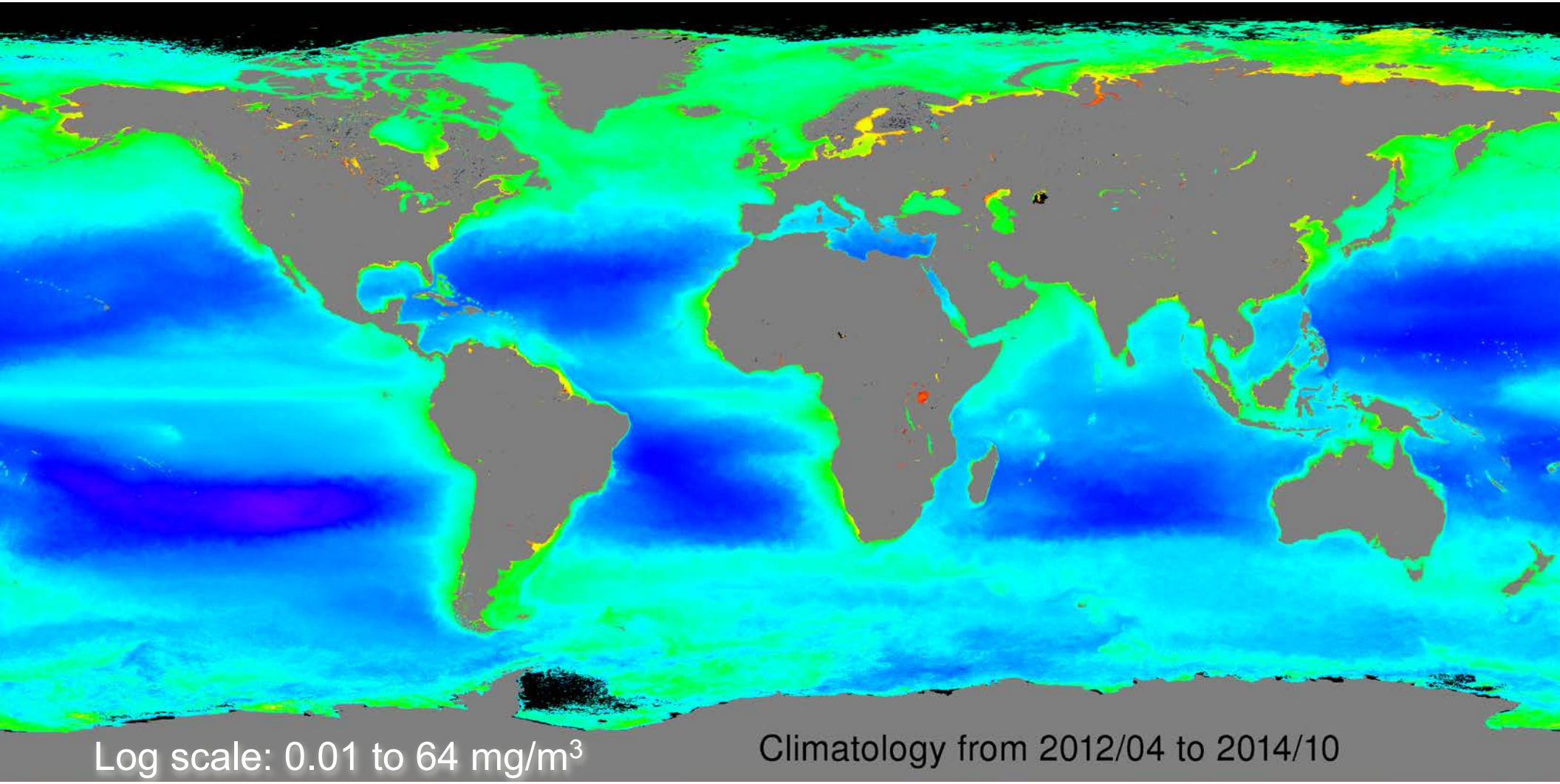
Software Download

Internal Access (password protected)

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

Menghua Wang, NOAA/NESDIS/STAR

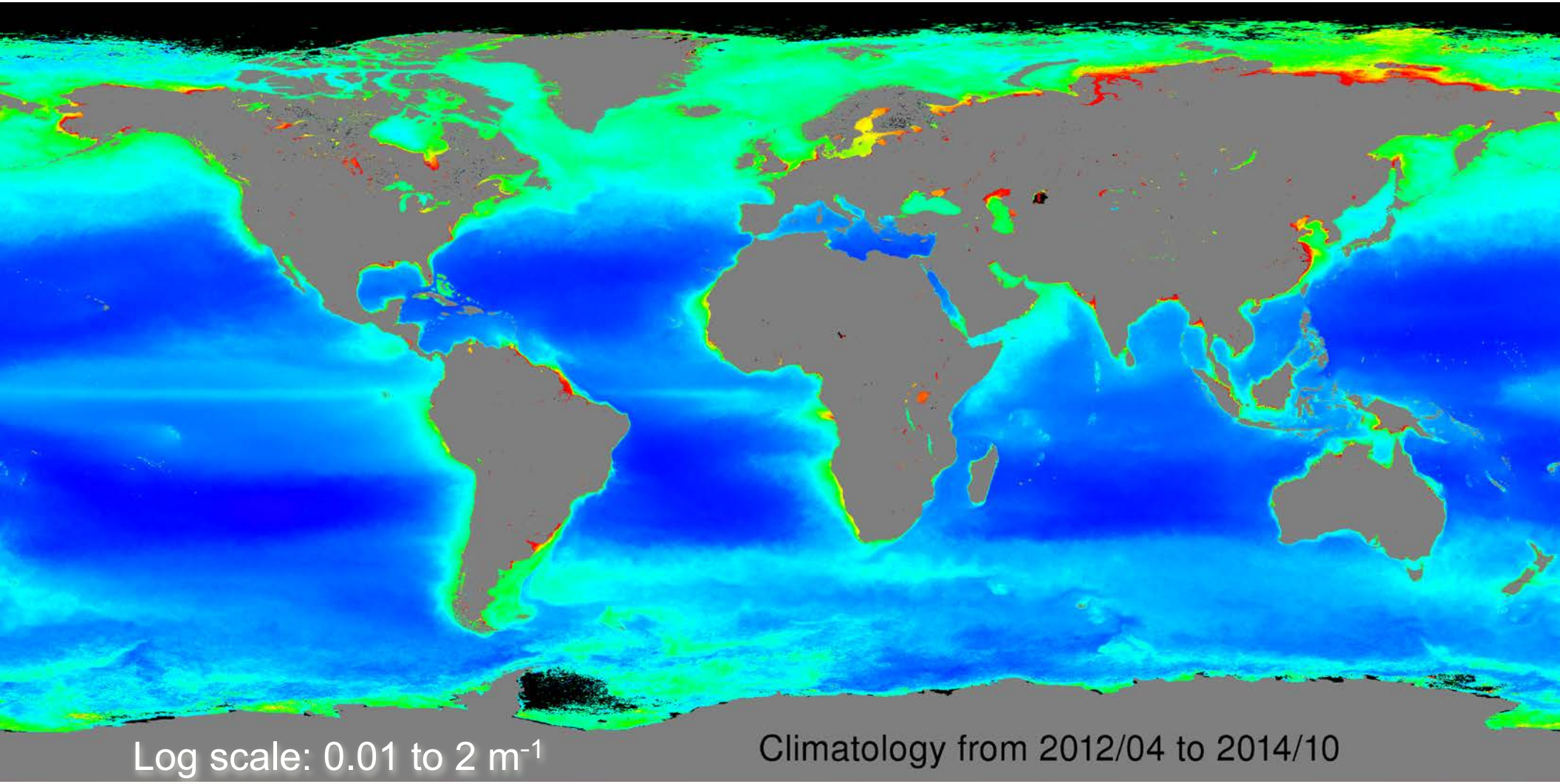
VIIRS Climatology Chlorophyll-a Image
(April 2012 to October 2014)



Generated using NOAA-MSL12 for VIIRS ocean color data processing

Menghua Wang, NOAA/NESDIS/STAR

VIIRS Climatology K_d(490) Image
(April 2012 to October 2014)



Generated using NOAA-MSL12 for VIIRS ocean color data processing

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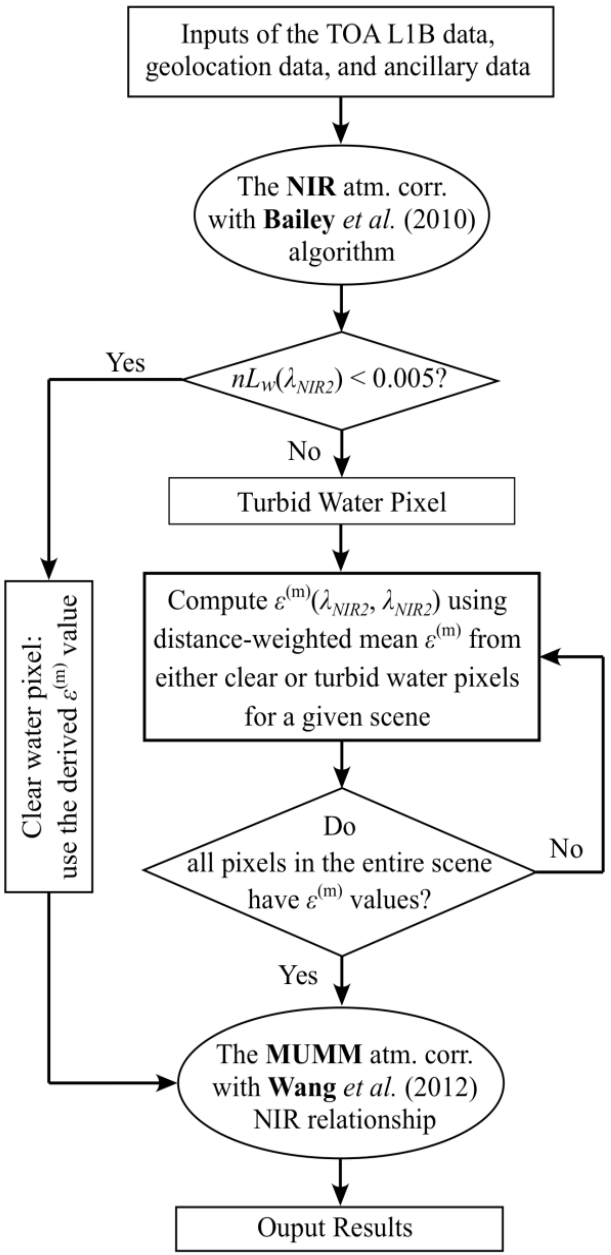
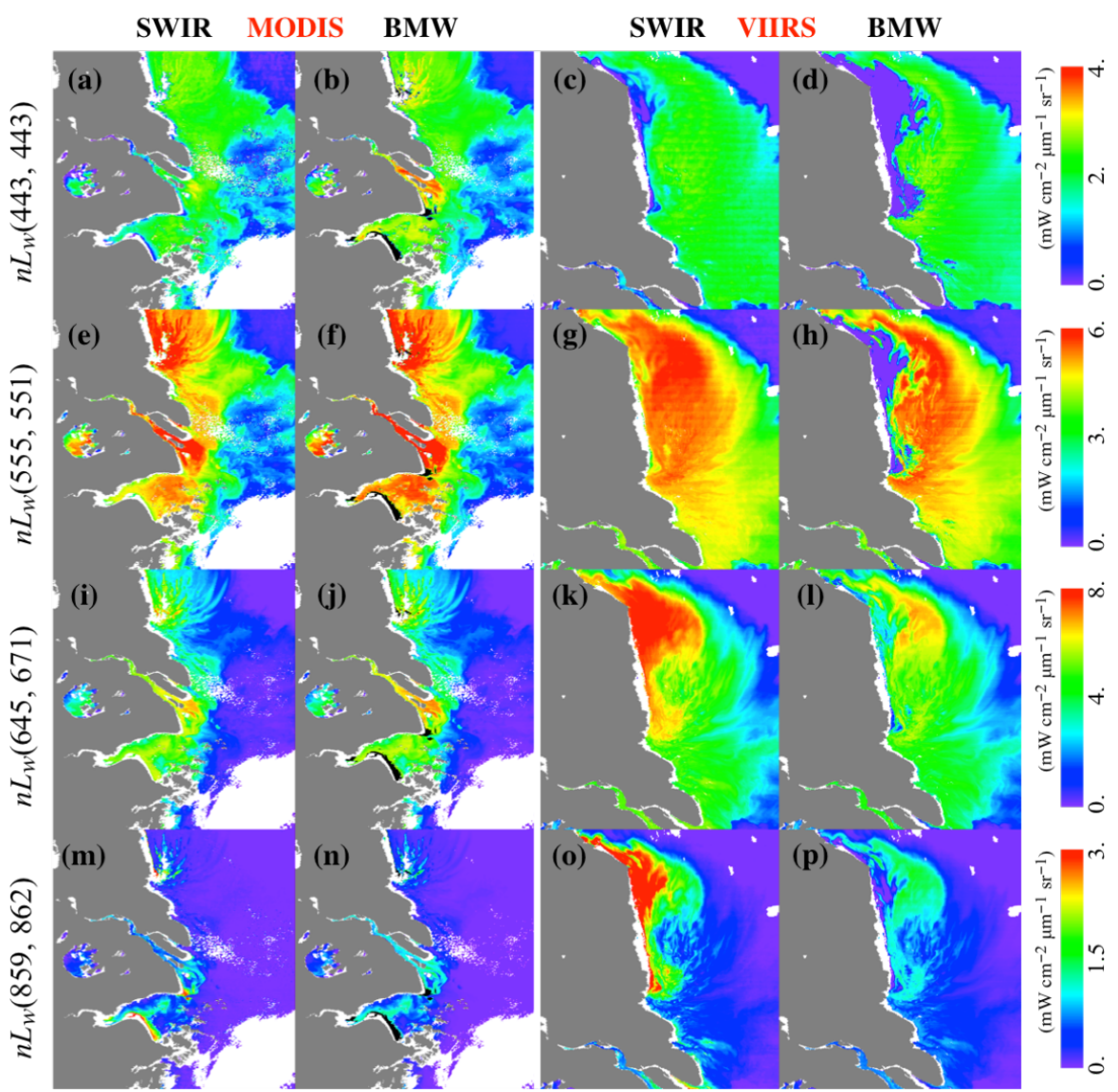
Developed a new NIR ocean reflectance correction algorithm: BMW (*Bailey* (2010), *MUMM* (2000), and *Wang* (2012))

The BMW Algorithm for Ocean Color Data Processing





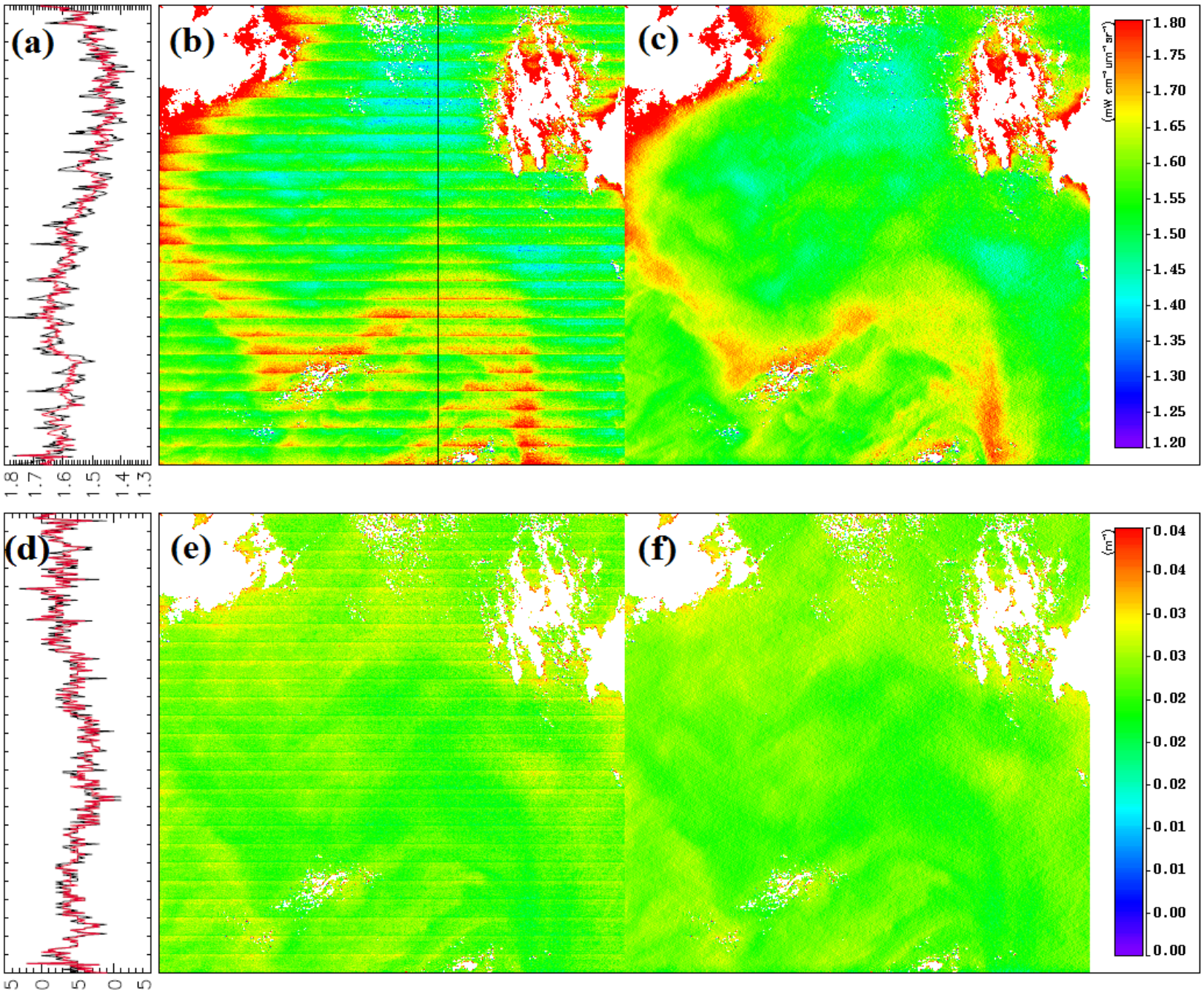
Comparisons of MODIS and VIIRS-derived $nL_w(\lambda)$ images at four selected bands.

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

Destriping of VIIRS Ocean Color Products
(Examples)

$nL_w(412)$

$K_d(490)$

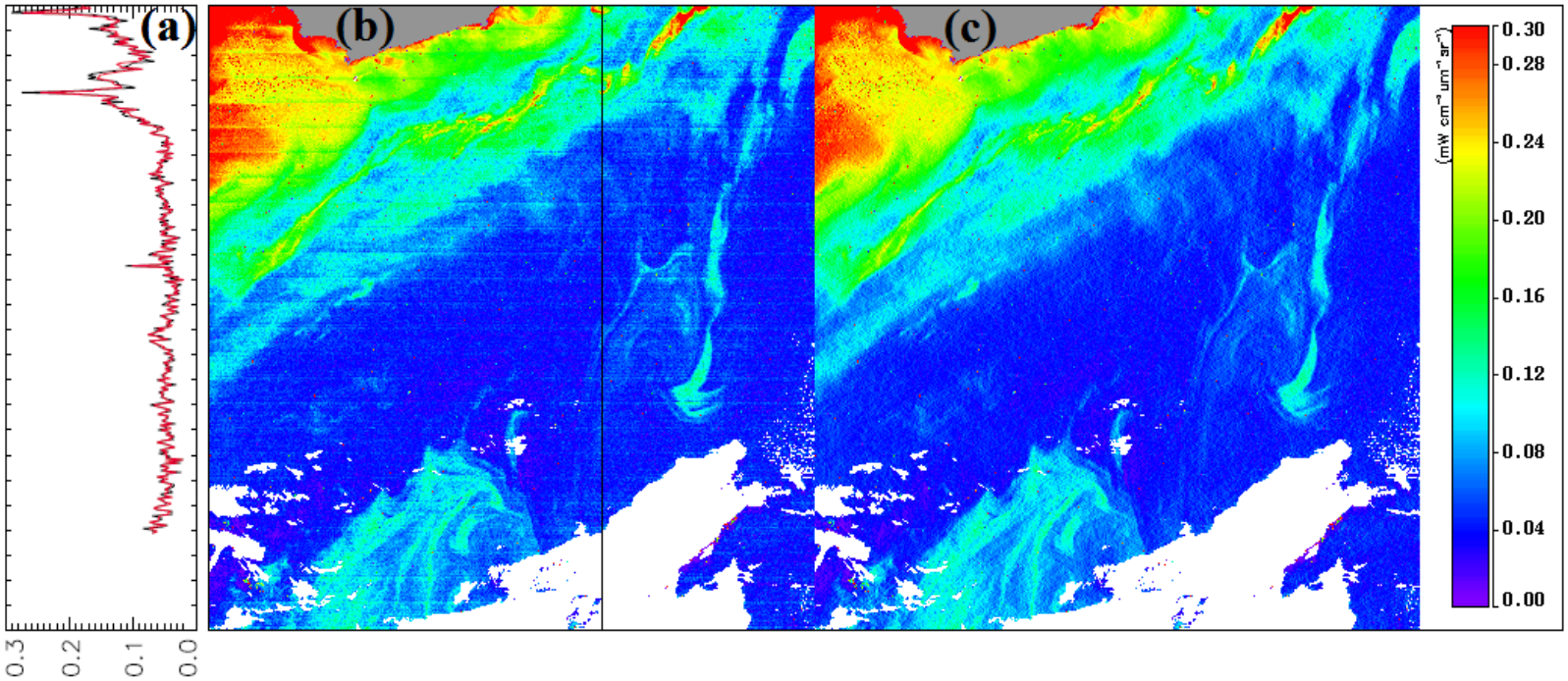


Mikelsons, K., M. Wang, L. Jiang, and M. Bouali, "Destriping algorithm for improved satellite-derived ocean color product imagery," *Opt. Express,* **22**, 28058-28070, 2014. http://dx.doi.org/10.1364/OE.22.028058

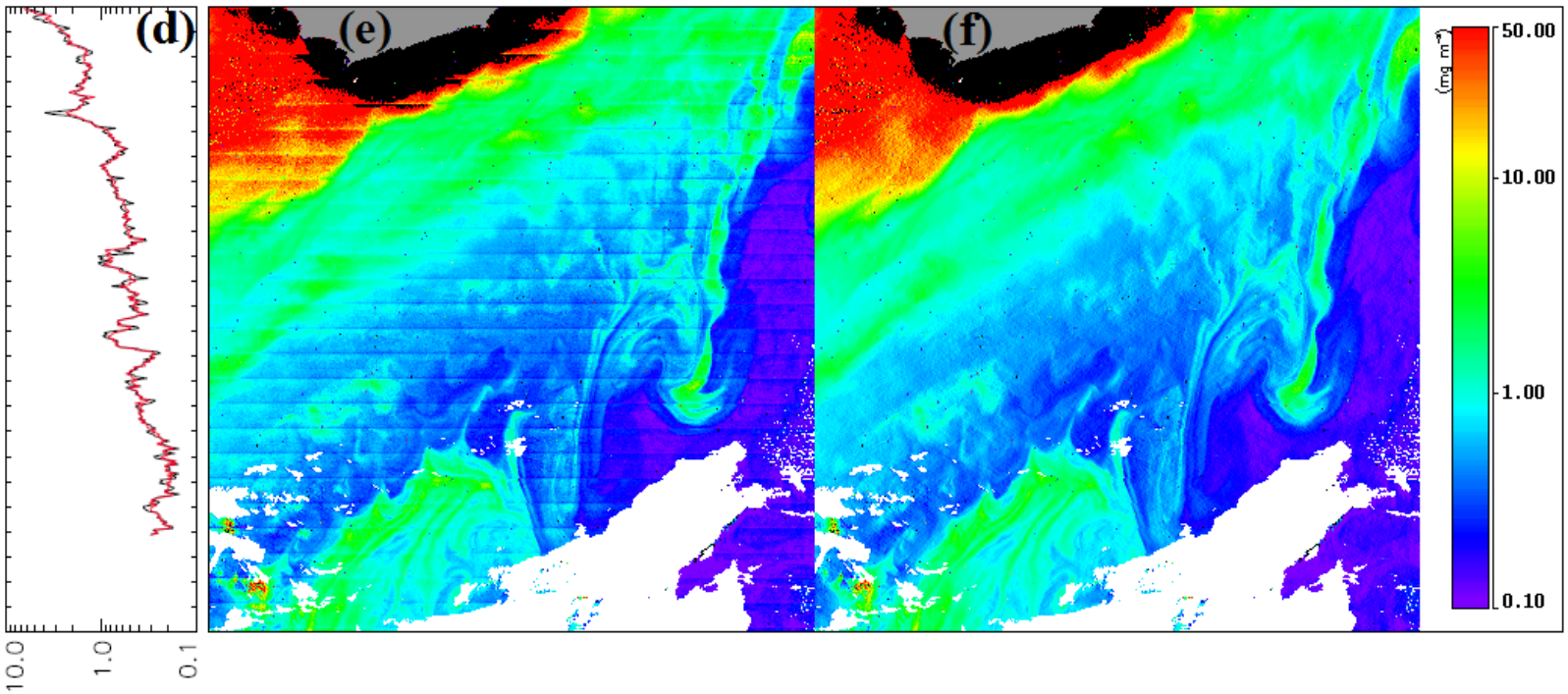
Destriping of VIIRS Ocean Color Products

(Examples)

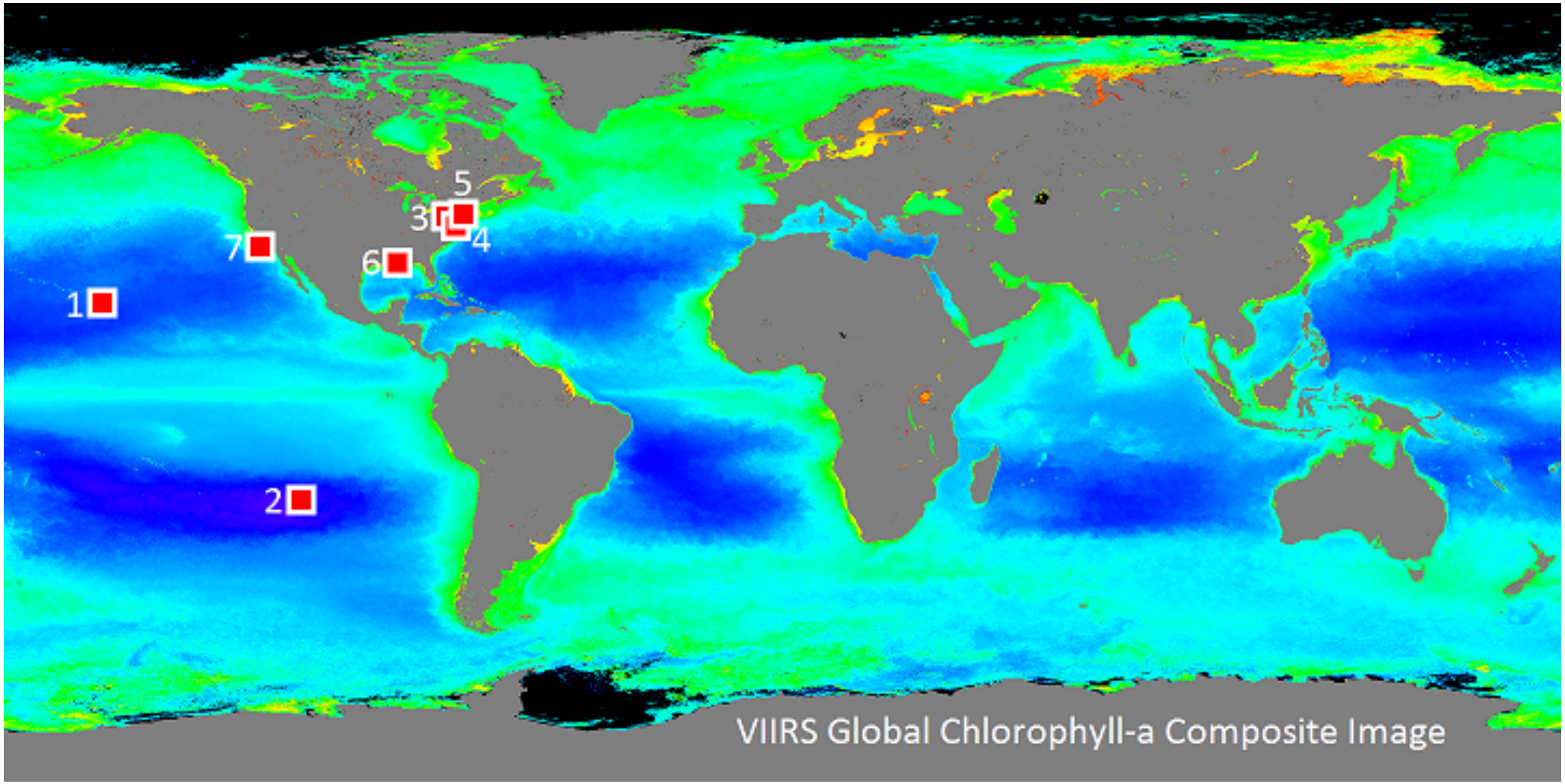
$nL_w(671)$



Chlorophyll-a



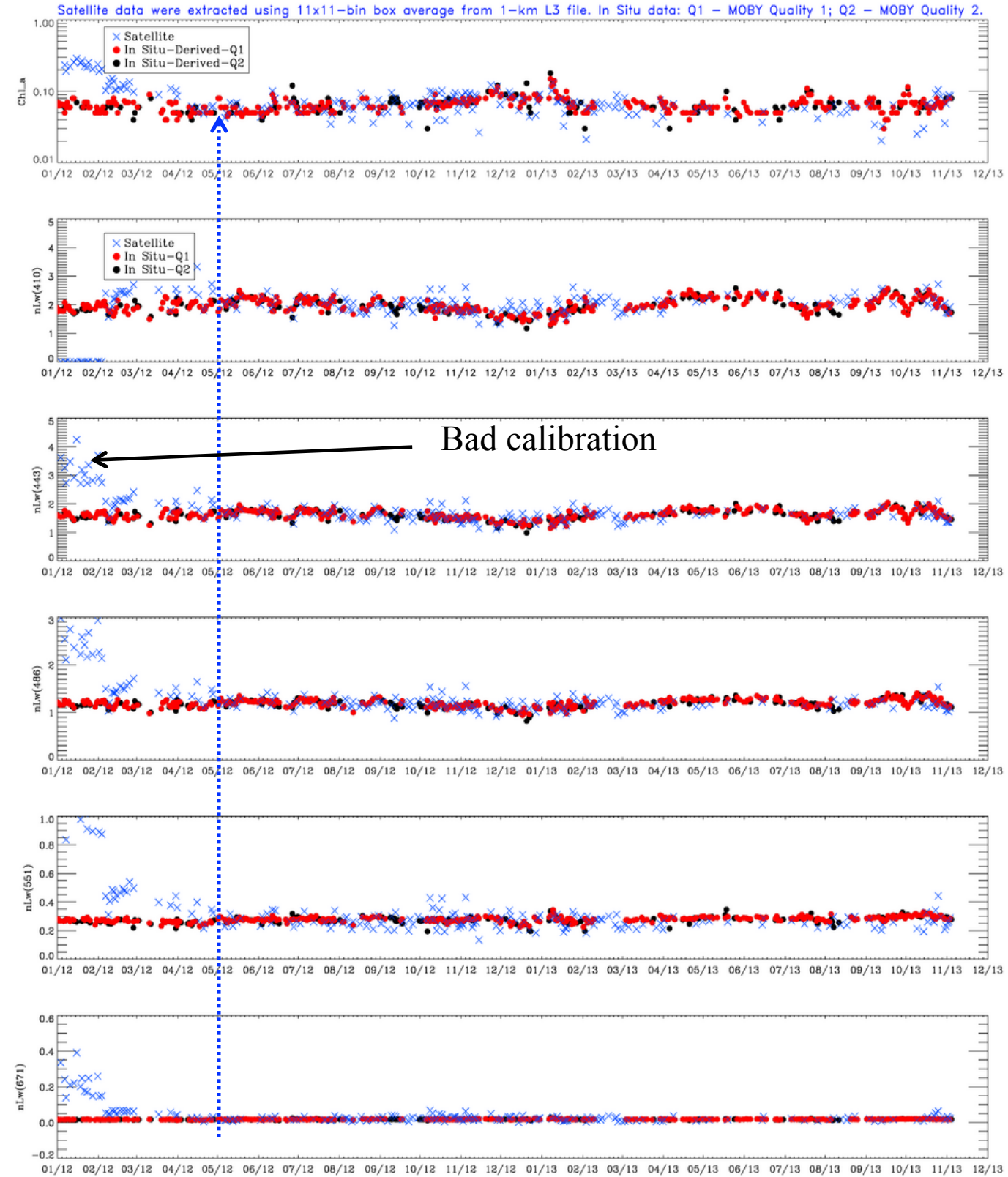
VIIRS Ocean Color EDR Monitoring Sites



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/



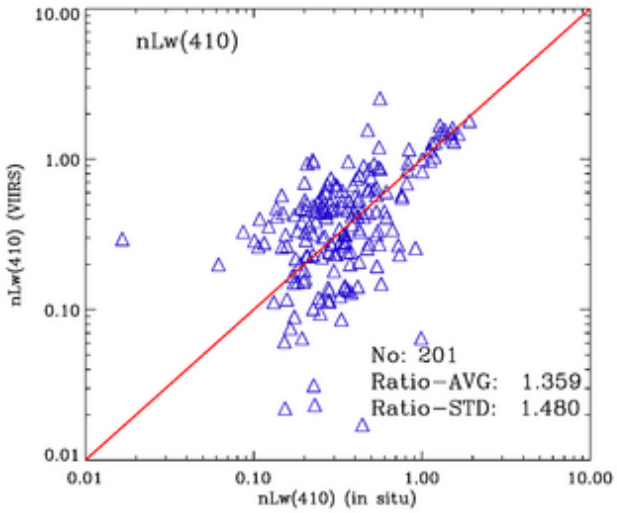
MOBY

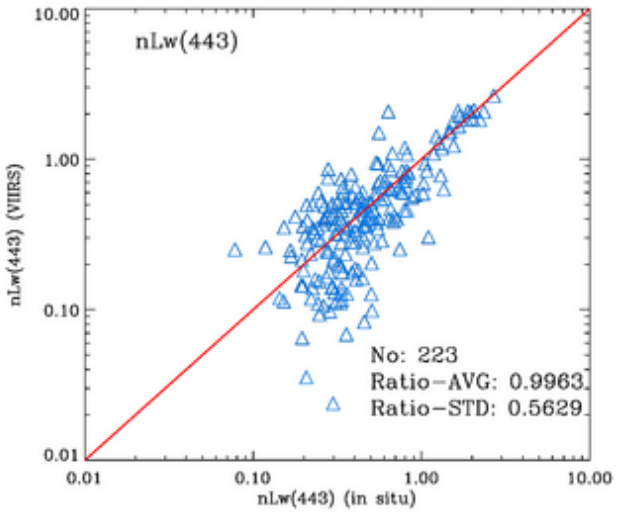
Comparison of NOAA VIIRS ocean color products with **Marine Optical Buoy (MOBY)** in situ data.

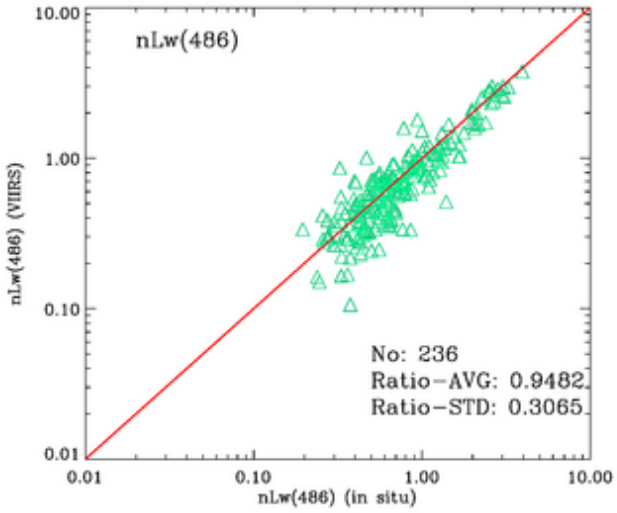
Note:
Vicarious calibration gains applied since **May 2012**.

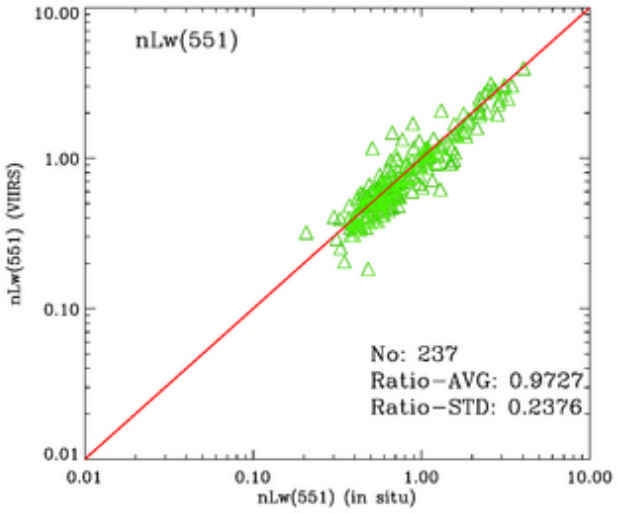
Vicarious gains were derived using **MOBY** in situ data.

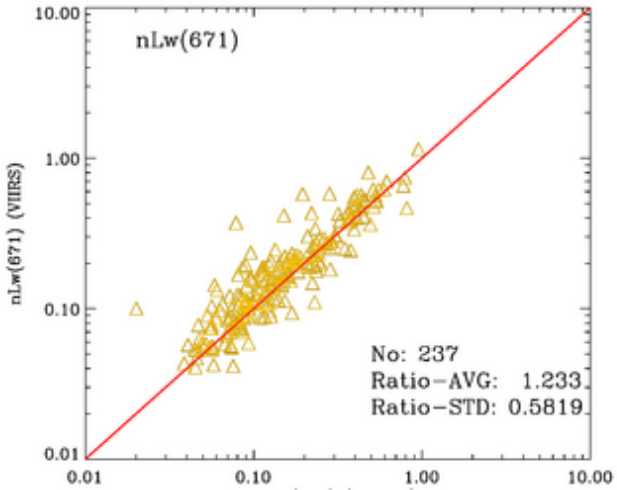
MOBY in situ optics data have been providing critical data set in support of VIIRS calibration and validation activities, including VIIRS Level-1B (SDR) data monitoring for sensor on-orbit calibration.

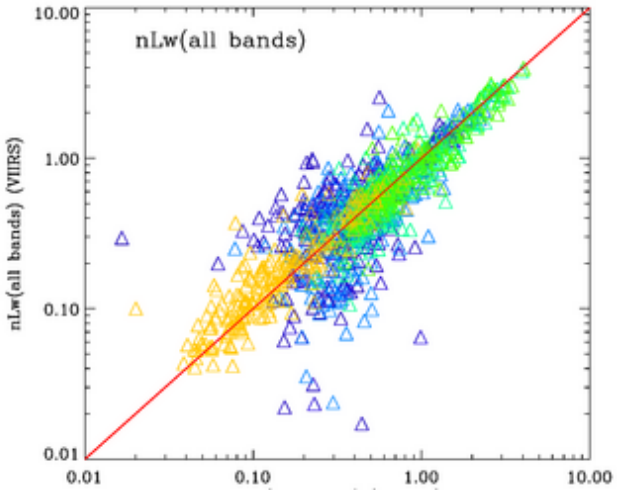












AERONET-OC

CSI Site

nL_w scatter plot

Gulf of Mexico

Dedicated VIIRS Cal/Val Cruise

NOAA Ship *Nancy Foster*

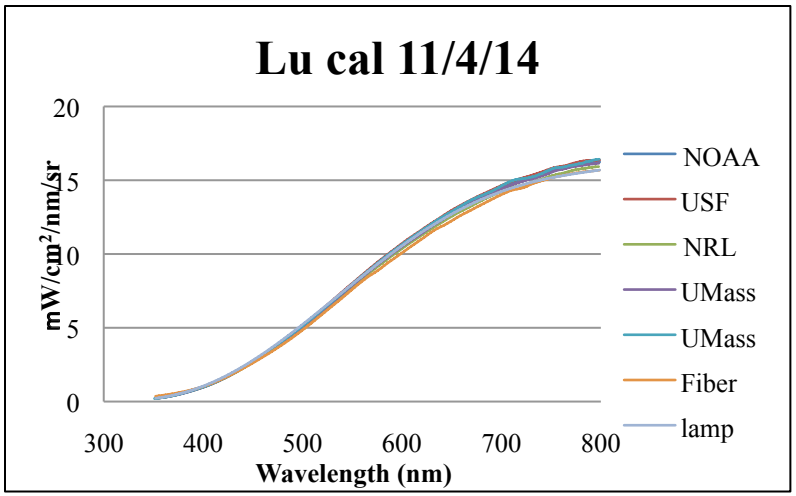
11-21 November 2014

International, Interagency, and Academic Collaborations:

4 US Agencies, EU-JRC, 6 Universities

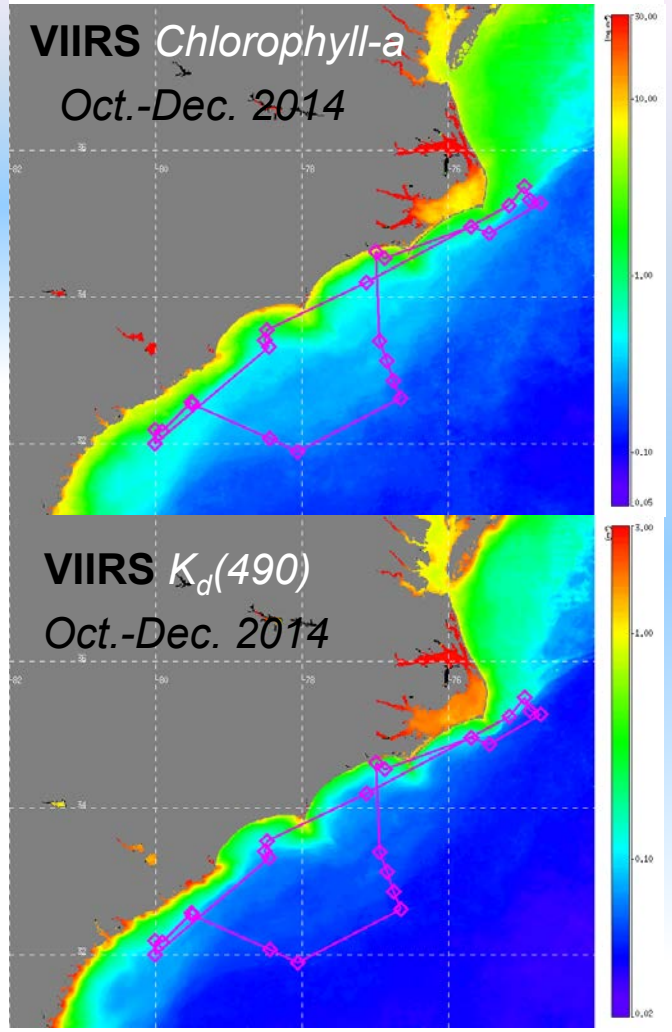
Validation Measurements

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

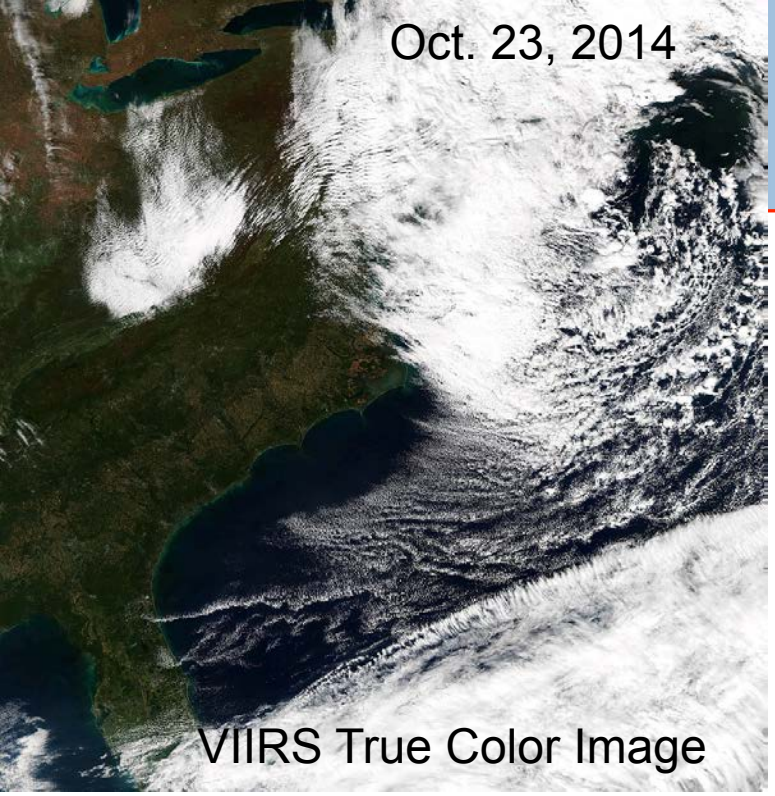
Cruise Track

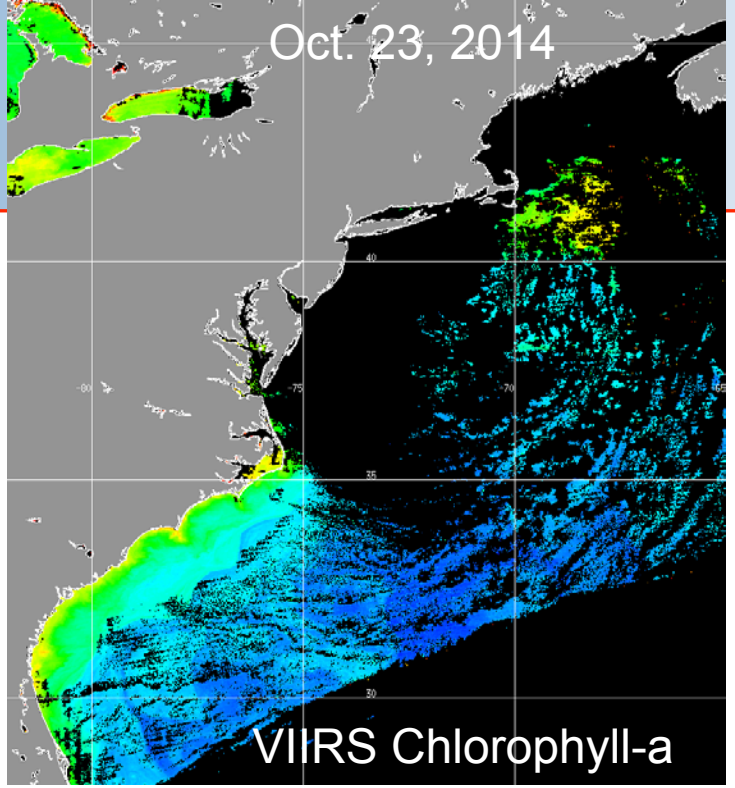


Validation Results

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

11 potential station matchups with VIIRS

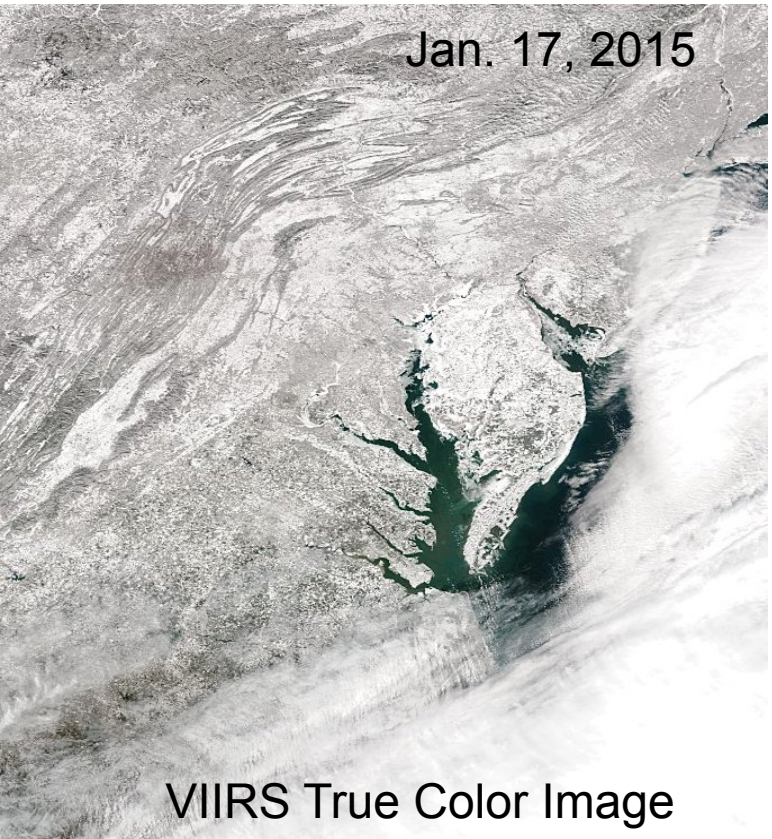


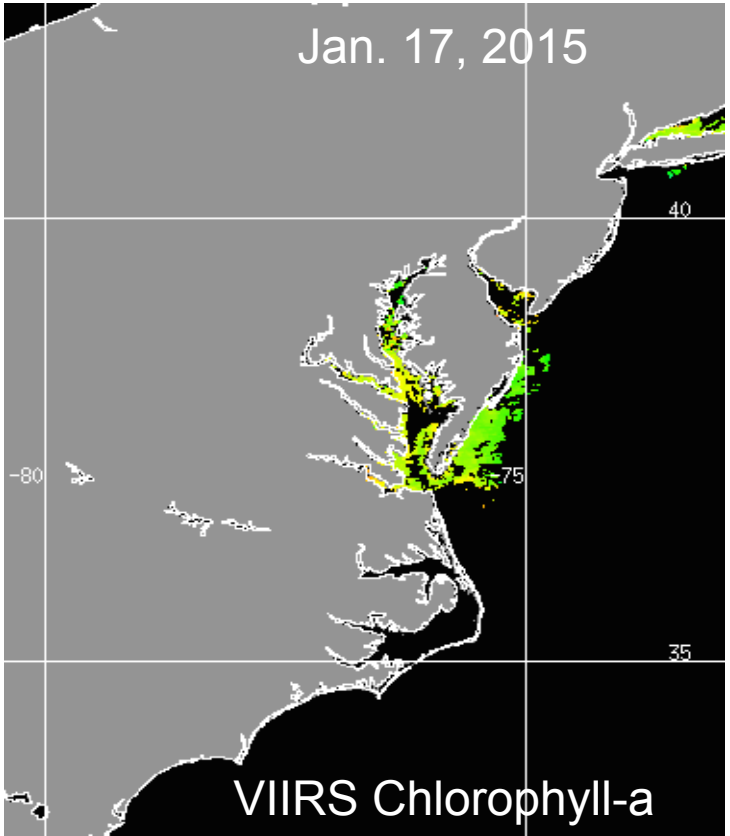


Data Monitoring:

US East Coast

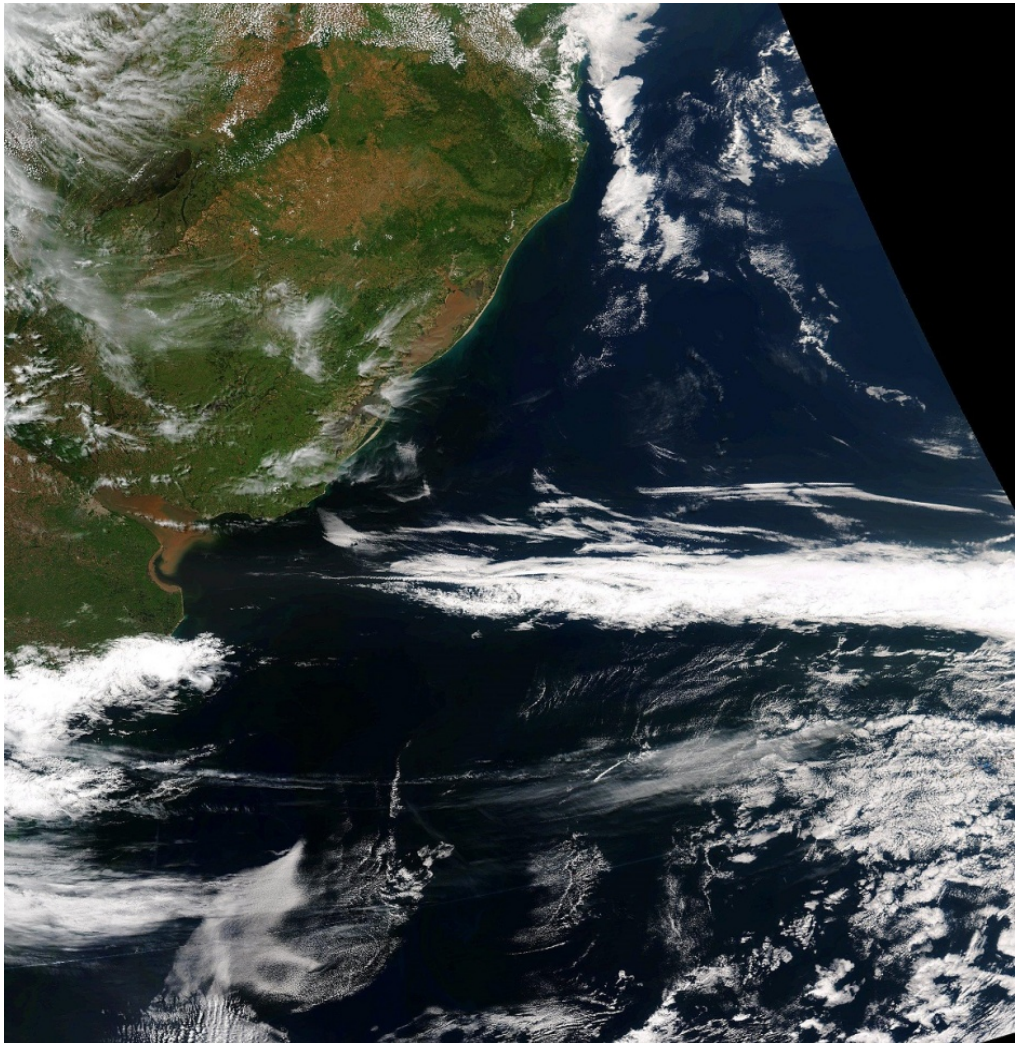
(Routine Daily Images for Various Coastal Sites)



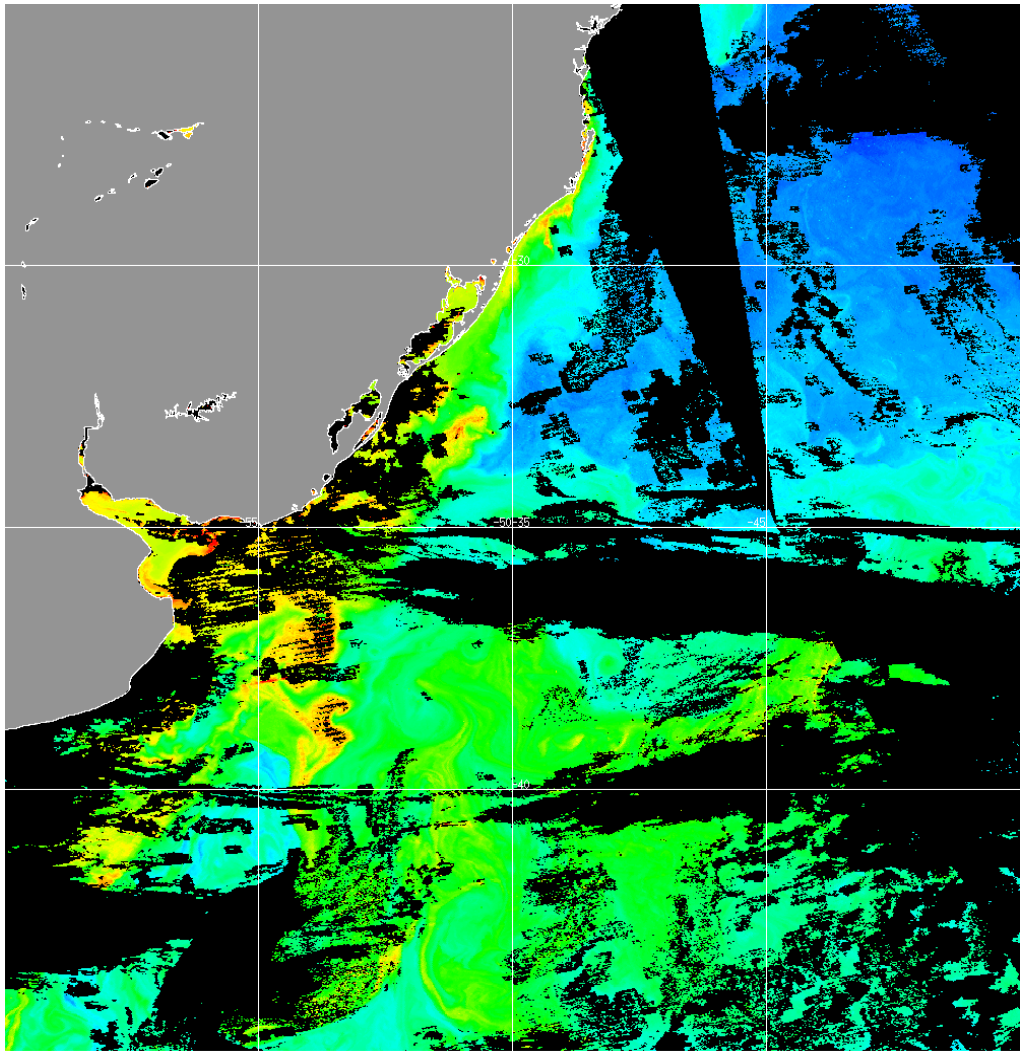


Data Monitoring: La Plata River, Oct. 23, 2014

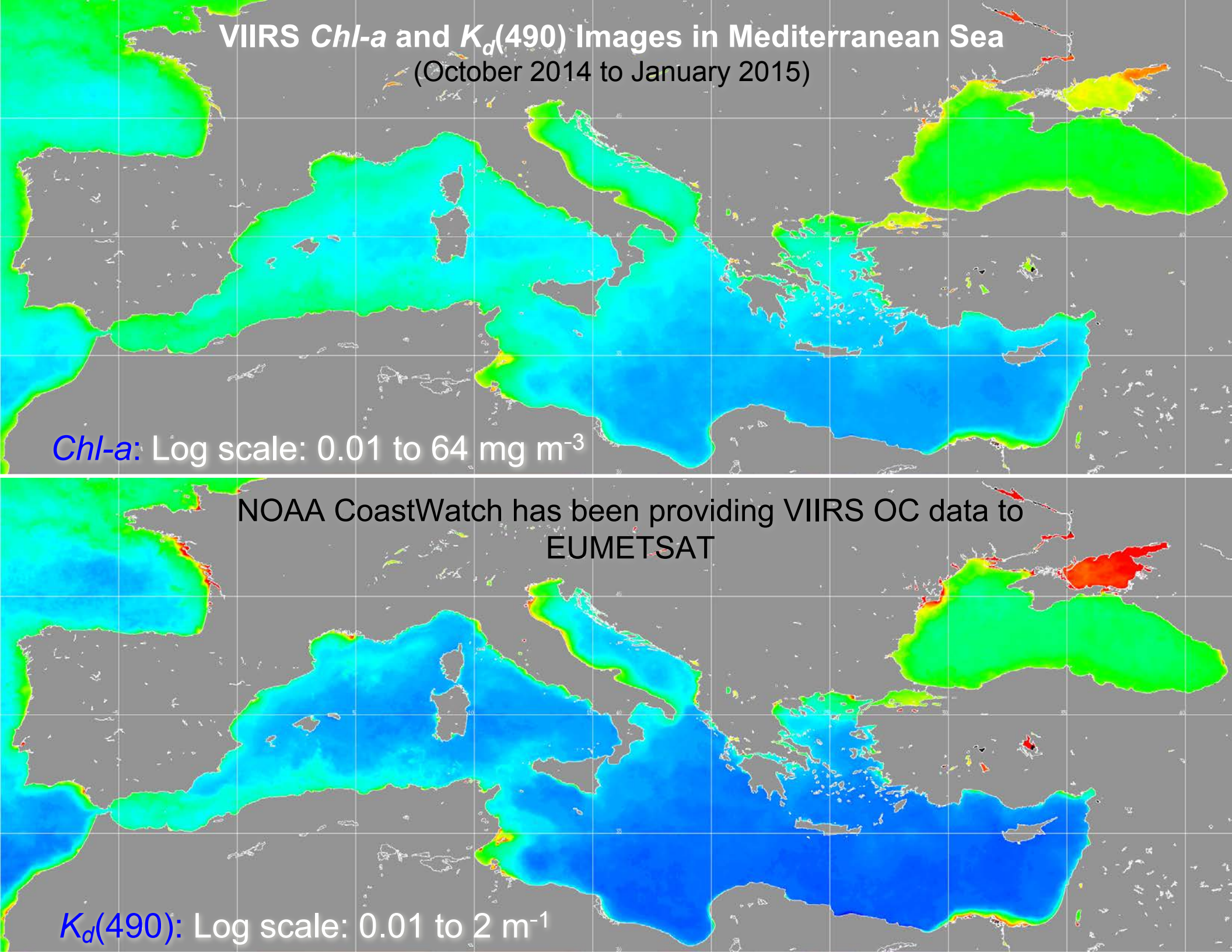
(Routine Daily Images from Various Coastal Sites)



VIIRS True Color Image



VIIRS Chlorophyll-a


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 Tools for Reef Managers

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

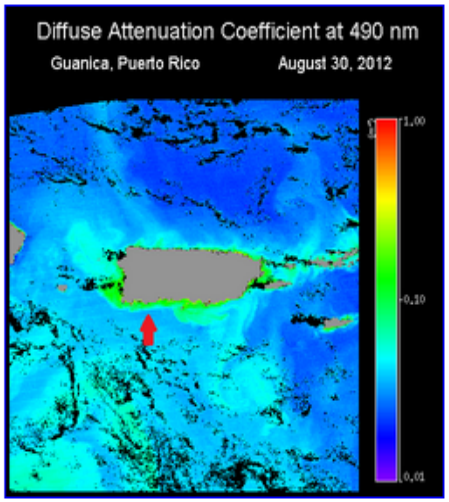
NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

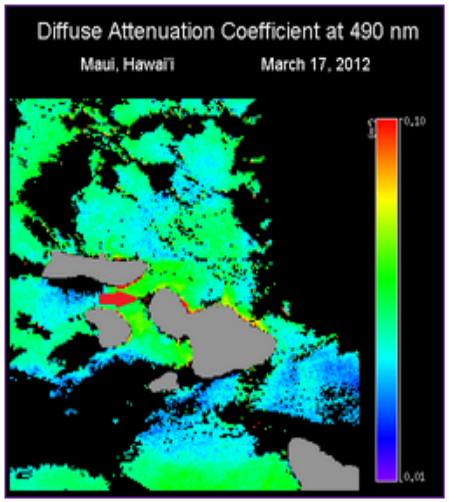
Coral Reef Watch

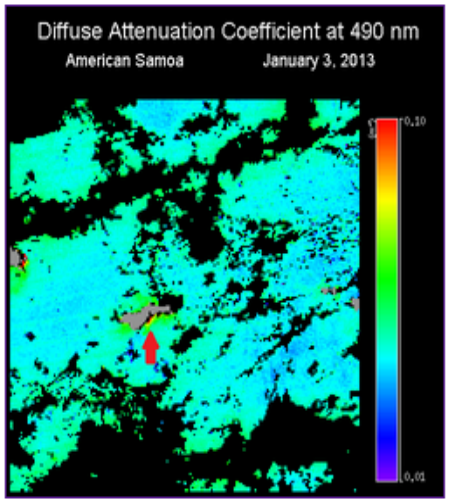
DOC > NOAA > NESDIS > STAR > CRW

CRTF | CRCP | CREIOS | CoRIS

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).

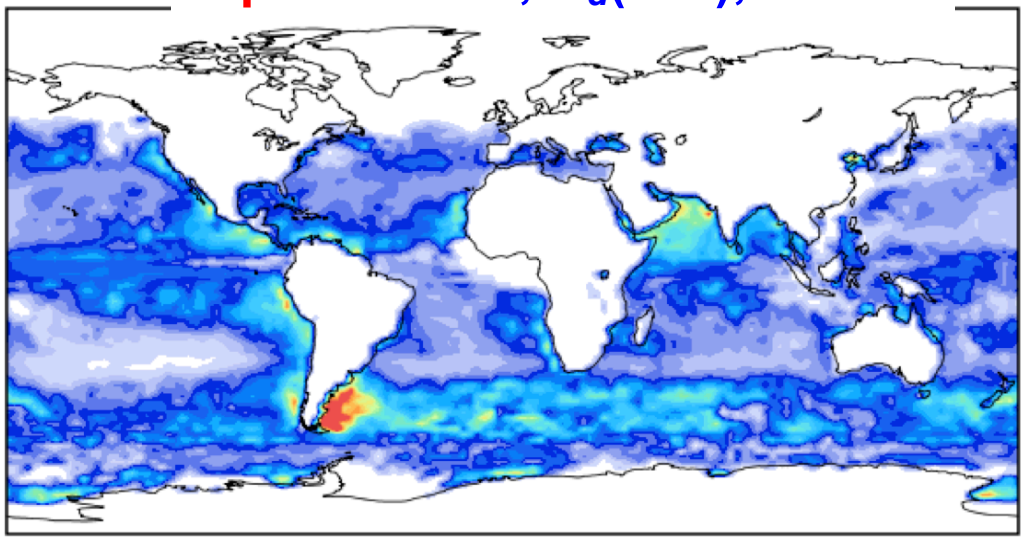
*From **Coral Reef Watch***

Global Distribution of Marine Isoprene Emission

Tong et al. (JPSS Proving Ground Project)

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

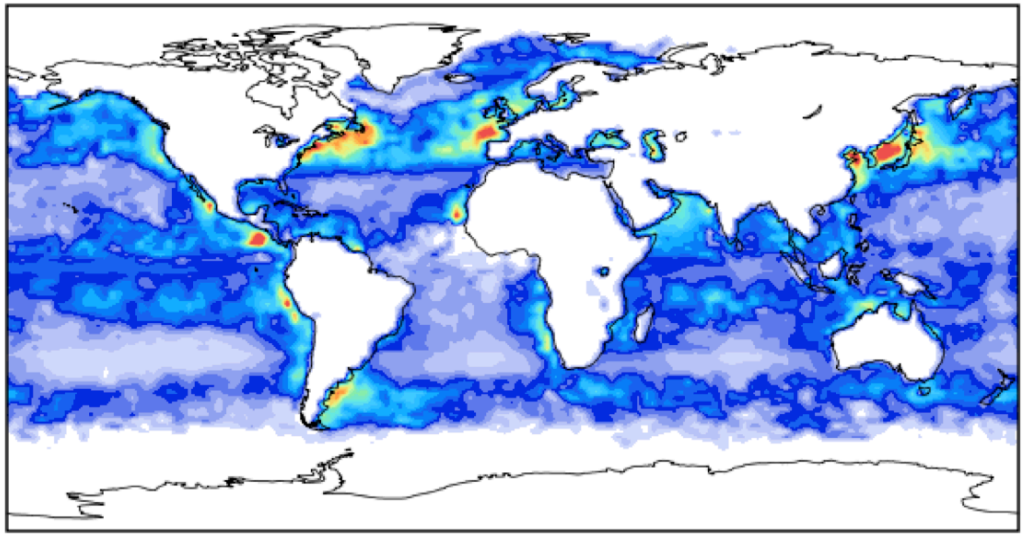
JAN



Marine Isoprene Emissions (molecules/cm2/s)

0.0E+00 1.0E+05 2.0E+05 3.0E+05

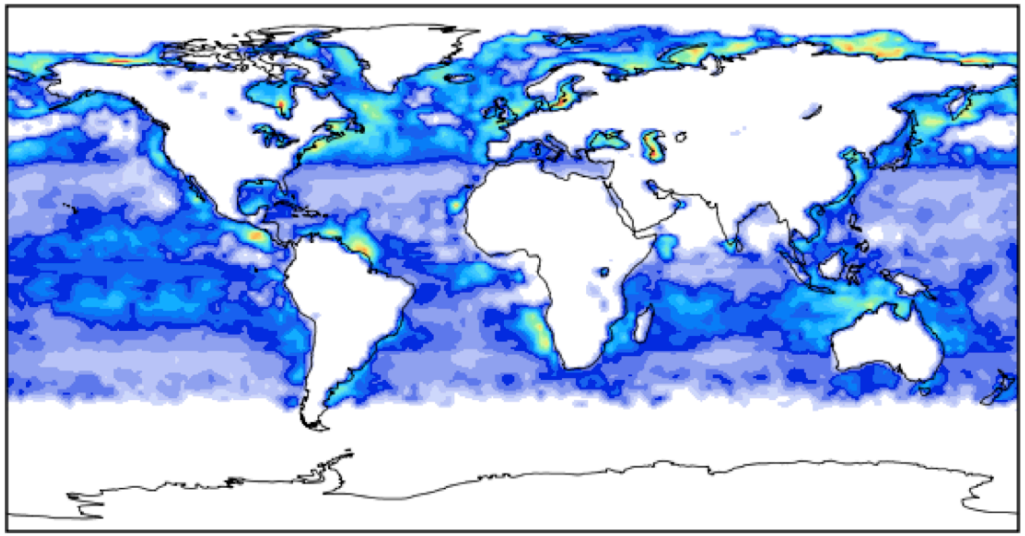
APR



Marine Isoprene Emissions (molecules/cm2/s)

0.0E+00 1.0E+05 2.0E+05 3.0E+05

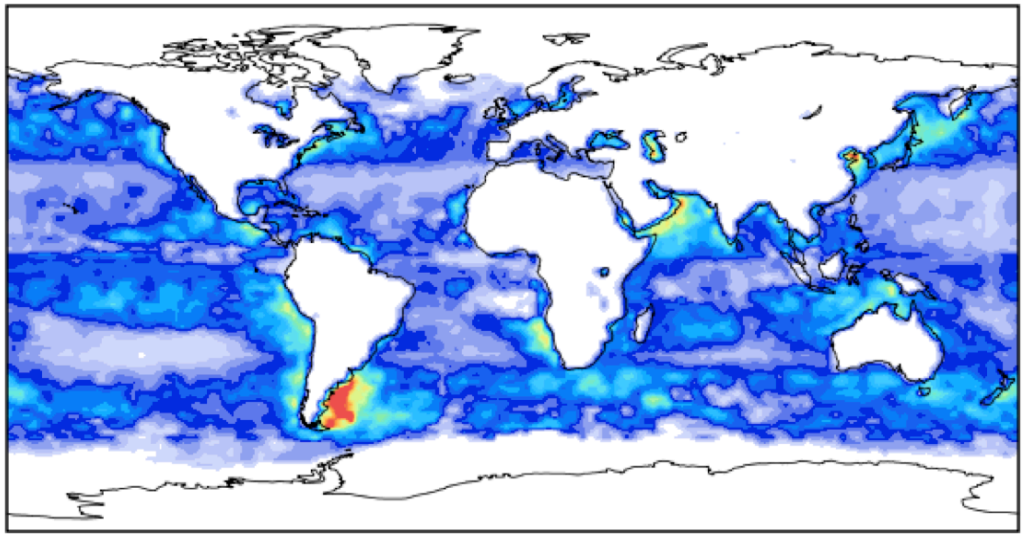
JUL



Marine Isoprene Emissions (molecules/cm2/s)

0.0E+00 1.0E+05 2.0E+05 3.0E+05

OCT



Marine Isoprene Emissions (molecules/cm2/s)

0.0E+00 1.0E+05 2.0E+05 3.0E+05

Conclusions

- VIIRS ocean color products have been improved after the implementation of some important updates, new algorithms, and with vicarious calibrations.
- In general, VIIRS **normalize water-leaving radiance** spectra show reasonable agreements with in situ measurements at MOBY, AERONET-OC sites, and various other ocean regions.
- The new NIR ocean reflectance correction algorithm (**BMW**) improves ocean color data over coastal and inland waters using the NIR-based atmospheric correction. The destriping algorithm significantly improves VIIRS-derived ocean color imageries.
- New K_d**(PAR)** product has been developed and routinely produced to meet the requirement from NOAA NWS users.
- There are several applications using VIIRS ocean color products.
- We have developed VIIRS instrument calibration capability, and with new calibration LUTs, VIIRS ocean color products are significantly improved.
- Although there are still some issues, our evaluation results show that VIIRS-SNPP is capable of providing high-quality global ocean color products in support of science research and operational applications.
- We have been actively working with other current and future ocean color sensors, e.g., MODIS-Aqua, Korean GOCI, EUMETSAT for Sentinel-3 (launch 2015), JAXA GCOM-C (launch early 2017), and **VIIRS on J1** (launch 2017).
- We are preparing VIIRS mission-long ocean color data **reprocessing** in couple months.

Website:

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

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

Thank You!