JPSS STAR Science Team Annual Meeting

12-16 May 2014

VIIRS EDR Ocean Color Team

Menghua Wang

VIIRS EDR Ocean Color Lead

13 May 2014

VIIRS Ocean Color Team Members' Roles & Responsibilities

EDR	Name	Organization	Funding Agency	Task
Lead	**Menghua Wang (EDR Lead), , L. Jiang, X. Liu, W. Shi, S. Son, L. Tan, X. Wang, P. Naik, J. Sun, V. Lance, K. Mikelsons, M. Ondrusek, E. Stengel**	NOAA/NESDIS/ STAR	JPSS/NJO	Leads – Ocean Color EDR 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, Giulietta Fargion**	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	USC	JPSS/NJO	Eureka (AERONET Site)
	Sam Ahmed, Alex Gilerson, Soe Hlaing	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, Nima Pahlevan	UMB	JPSS/NJO	Ocean color IOP data validation and evaluation Ocean color optics matchup
	Patty Pratt, J. Ip	NGAS	JPSS/NJO	Detector tool Matchup and DR and IDPS updates

Working with: VIIRS **SDR team**, DPA/DPE (e.g., R. Williamson, Neal Baker), Raytheon (e.g., Marine Hollingshead), NOAA OC Working Group, NOAA various line-office reps, NASA OC Working Group (K. Turpie, B. Franz , et al.), NOAA OCPOP, etc.
Collaborators: D. Antoine (BOUSSOLE), B. Holben (NASA-GSFC), G. Zibordi (JRC-Italy), and others

Summary of VIIRS OCC EDR Algorithms

- **Inputs**: VIIRS M1-M7 bands SDR data, terrain-corrected geo-location file, SST EDR data (not used for current OC3V chlorophyll-a algorithm), cloud mask Intermediate Product (IP), on-board calibrator IP, 7 ancillary data files, 7 lookup tables, and 1 configurable parameter file.

- **Outputs**: Chlorophyll-a (Chl-a) concentration, normalized water-leaving radiance (nLw's) at bands M1-M5, Inherent Optical Properties (IOP-a and IOP-s) at VIIRS bands M1-M5, and quality flags. Primary outputs are chlorophyll-a and normalized water-leaving radiances.

- There are three sets of algorithms in the IDPS OCC-EDR data processing:
  - The Gordon & Wang (1994) atmospheric correction algorithm: including corrections for ozone, Rayleigh (molecules) and aerosols, ocean surface reflection, sun glint, whitecap, and sensor polarization effects.
  - chlorophyll-a algorithm: currently with OC3V algorithm (heritage algorithm), with option to switch between the OC3V and Carder chlorophyll-a algorithms.
  - IOP algorithm: Carder IOP algorithm.

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

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 and common ocean color data processing for multiple satellite ocean color sensors (*Wang*, 1999; *Wang and Franz*, 2000; *Wang et al.*, 2002).
- ✓ It has been used for producing ocean color products from various satellite ocean color sensors, e.g., SeaWiFS, MOS, OCTS, POLDER, MODIS, etc.

➢ NOAA-MSL12 Ocean Color Data Processing

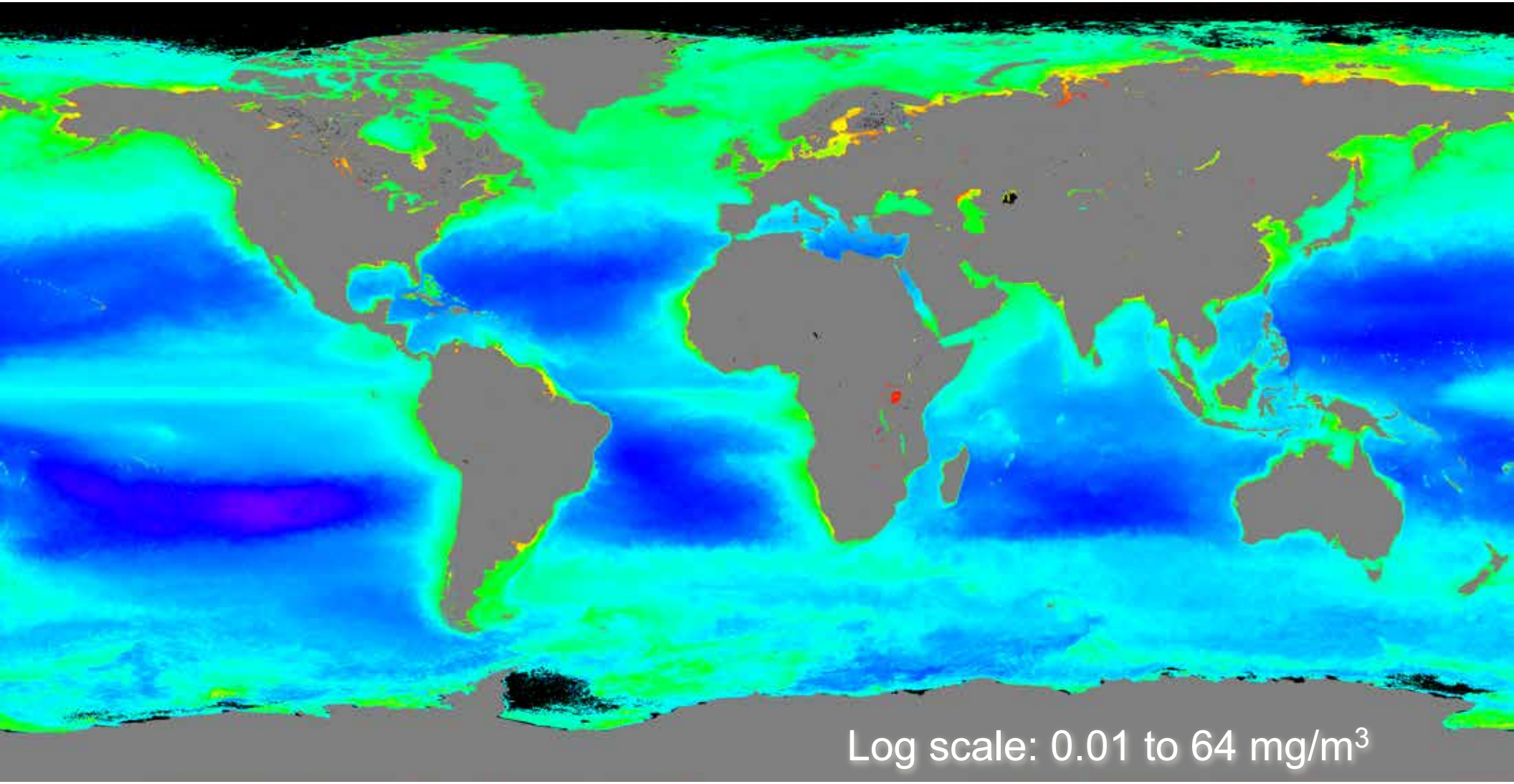
- ✓ NOAA-MSL12 is based on SeaDAS version 4.6.
- ✓ Some significant improvements: (1) the SWIR-based data processing, (2) Rayleigh and aerosol LUTs, (3) detecting absorbing aerosols and turbid waters, (4) ice detection algorithm, (5) improved straylight and cloud shadow algorithm, and others.
- ✓ Capability for multi-sensor ocean color data processing, e.g., MODIS, **VIIRS**, GOCI, and will add OLCI/Stentinel-3, SGLI/GCOM-C, **J-1**, **J-2**, and others.

➢ NOAA-MSL12 for **VIIRS** Ocean Color Data Processing

- ✓ Standard ocean color products: normalized water-leaving radiances ($nL_w(\lambda)$) at VIIRS M1 to M5 bands; chlorophyll-a concentration, and water diffuse attenuation coefficient at the wavelength of 490 nm ($K_d(490)$).
- ✓ Experimental products: photosynthetically available radiation (PAR), inherent optical properties (IOPs), and others.

Menghua Wang, NOAA/NESDIS/STAR

VIIRS Climatology Chlorophyll-a Image
(April 2012 to December 2013)

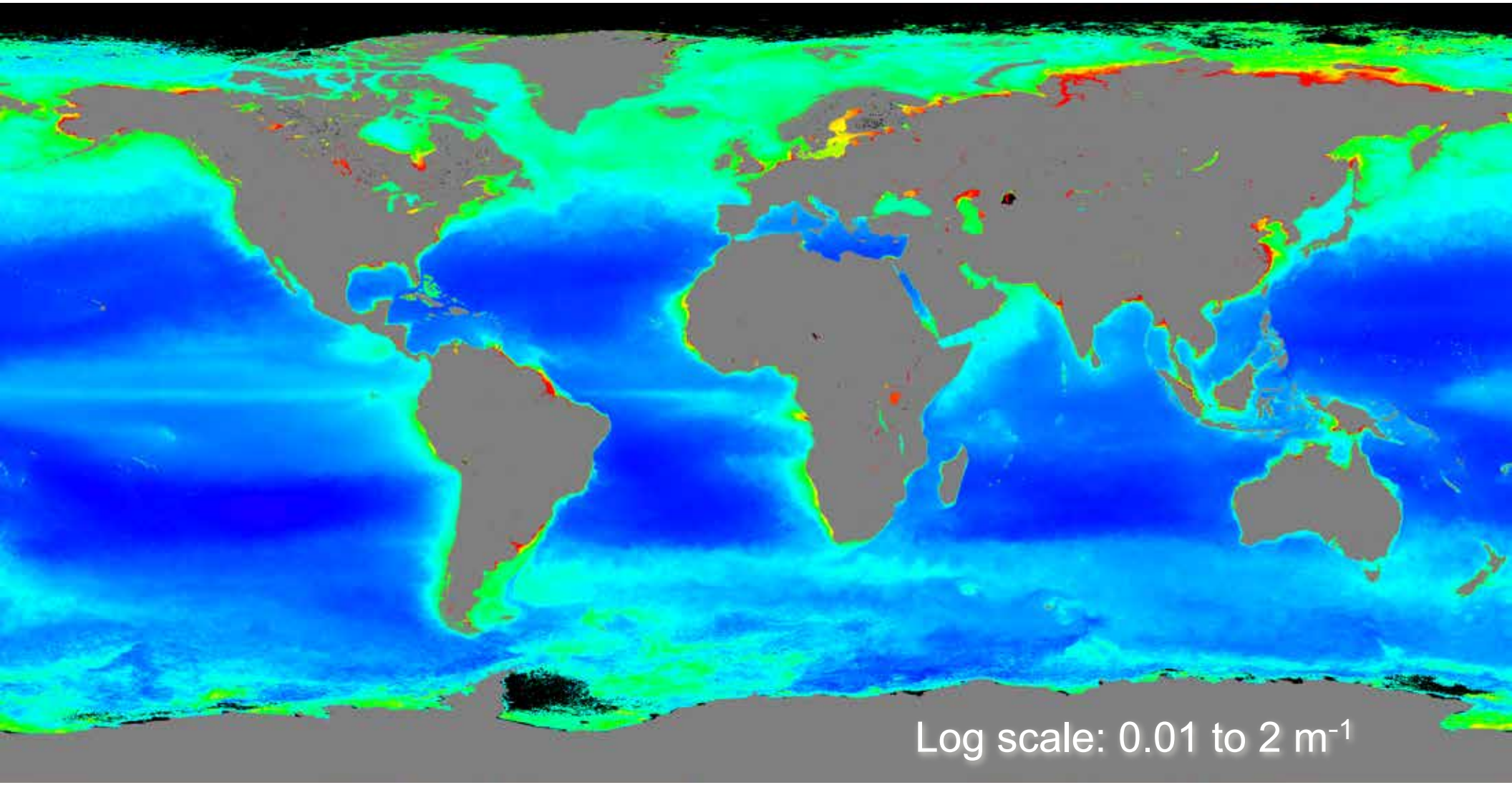


Generated using NOAA-MSL12 for VIIRS ocean color data processing

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
(April 2012 to December 2013)



Generated using NOAA-MSL12 for VIIRS ocean color data processing

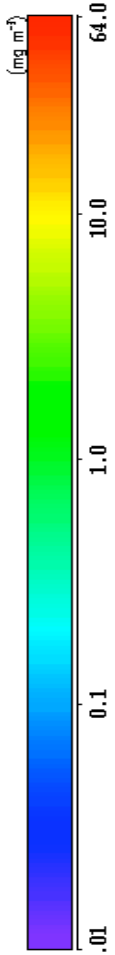
Wang, M., S. Son, and L. W. Harding, Jr., "Retrieval of diffuse attenuation coefficient in the Chesapeake Bay and turbid ocean regions for satellite ocean color applications," *J. Geophys. Res.*, **114**, C10011, 2009. http://dx.doi.org/10.1029/2009JC005286.

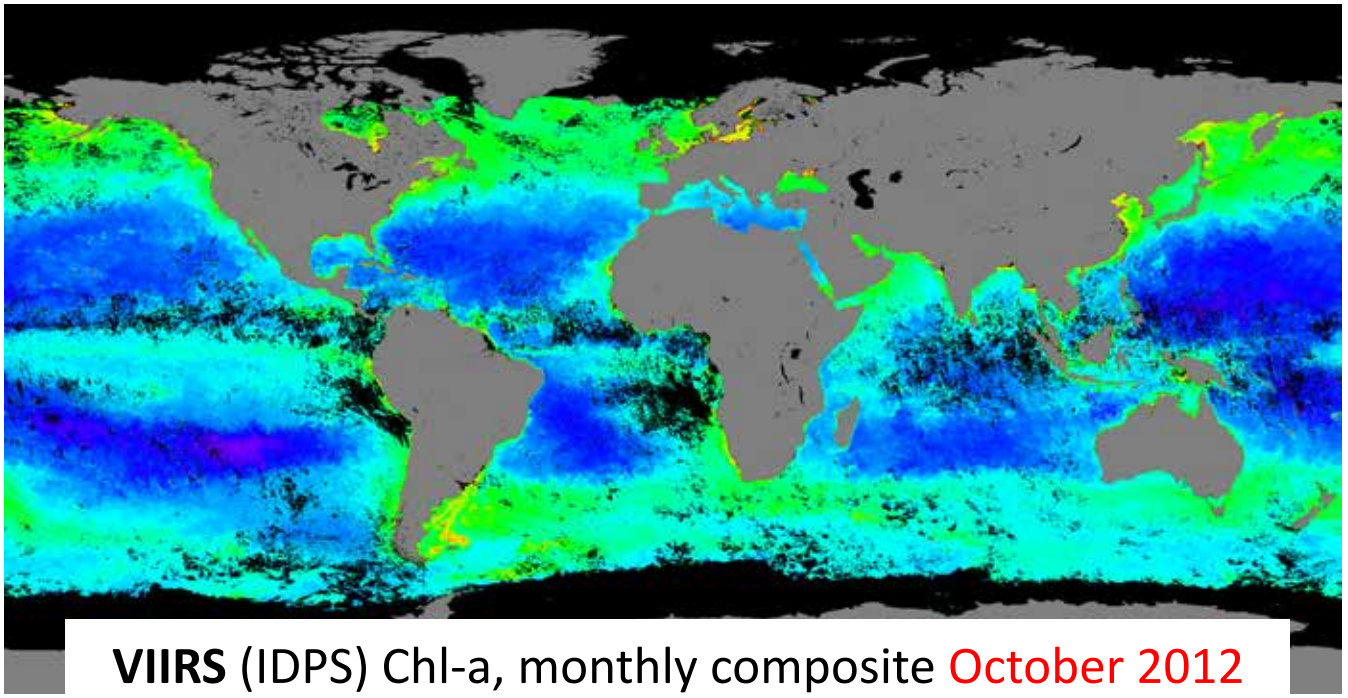
Menghua Wang, NOAA/NESDIS/STAR

VIIRS (IDPS) vs. MODIS-Aqua (Monthly)

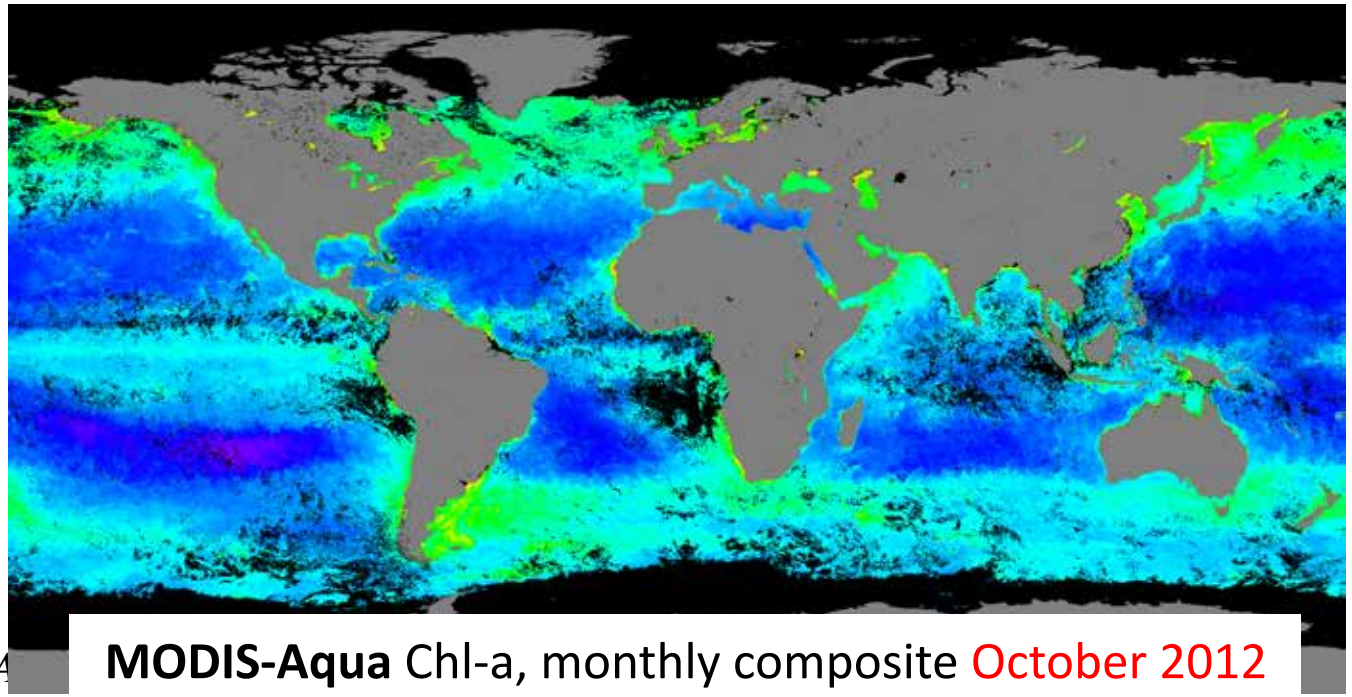
Chlorophyll-a

Log scale:
0.01 to 64 mg/m3





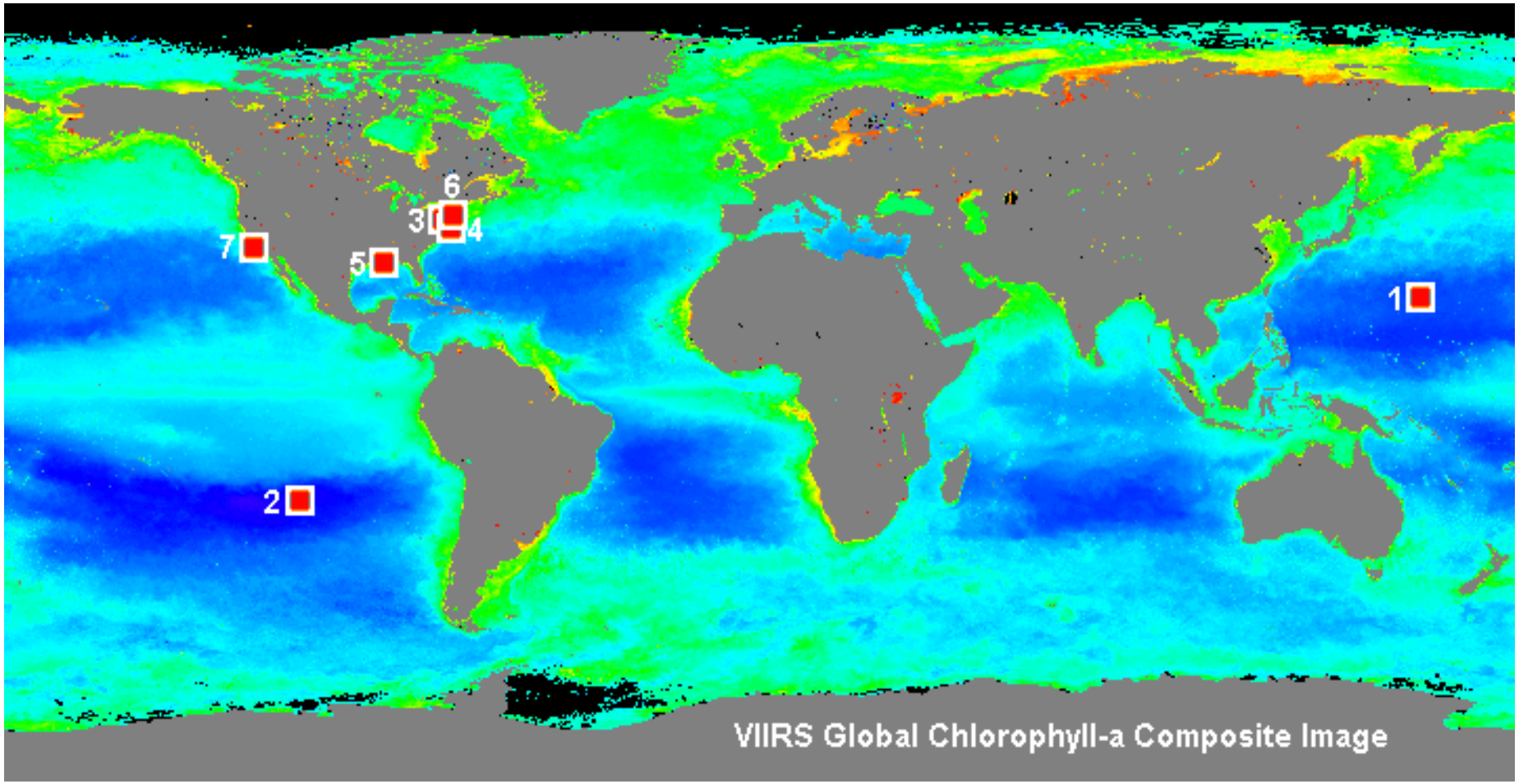
VIIRS (IDPS) Chl-a, monthly composite October 2012



MODIS-Aqua Chl-a, monthly composite October 2012

MODIS-Aqua data were obtained from NASA/ OBPG ocean color website.

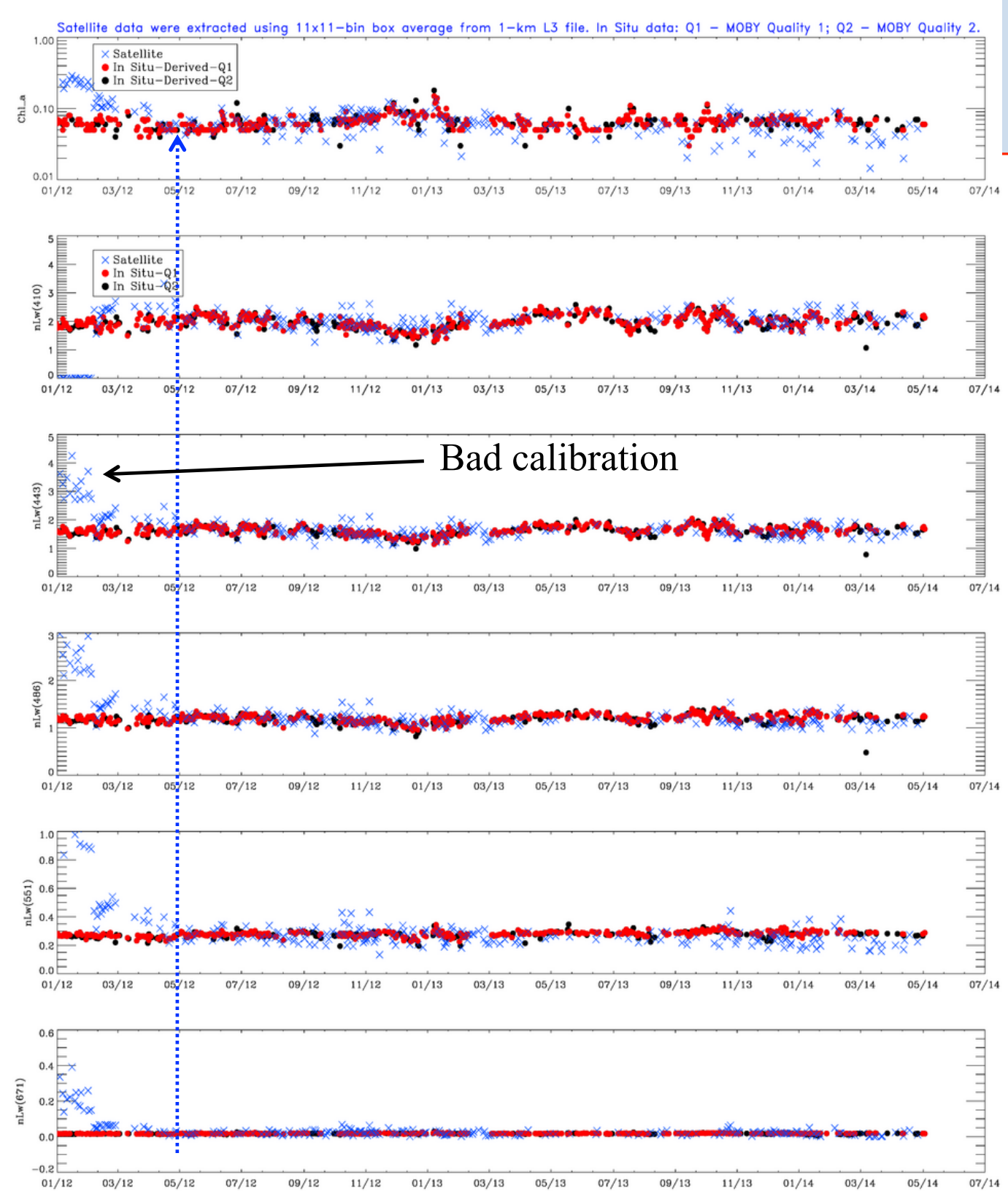
VIIRS Ocean Color EDR Monitoring Sites



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/



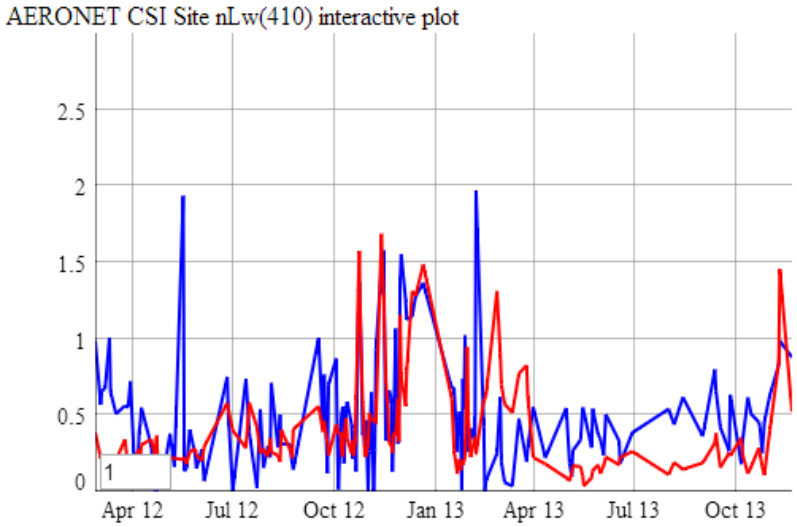
Comparison of VIIRS **NOAA-MSL12** results with MOBY in situ data.

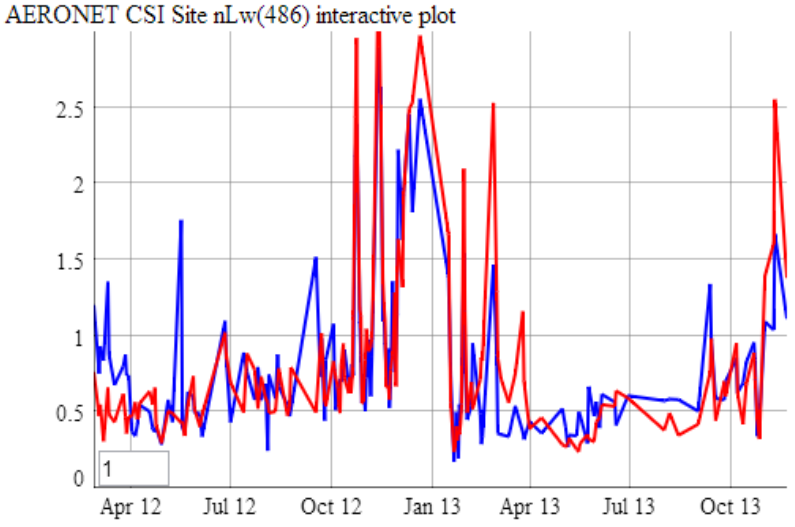
Note:
Vicarious calibration gains applied since **May 2012**.

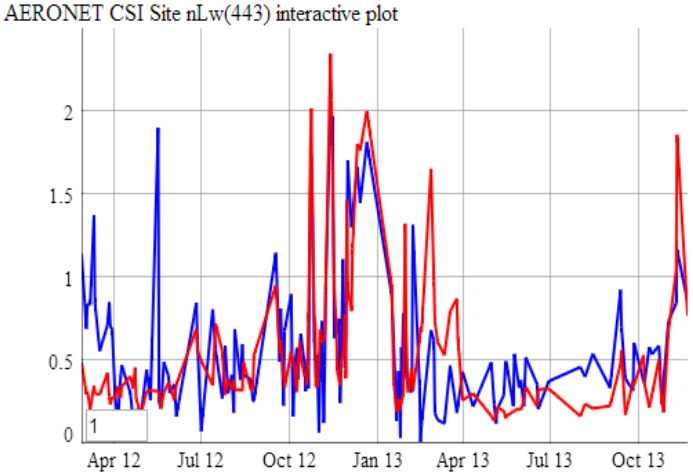
Gains derived using MOBY data.

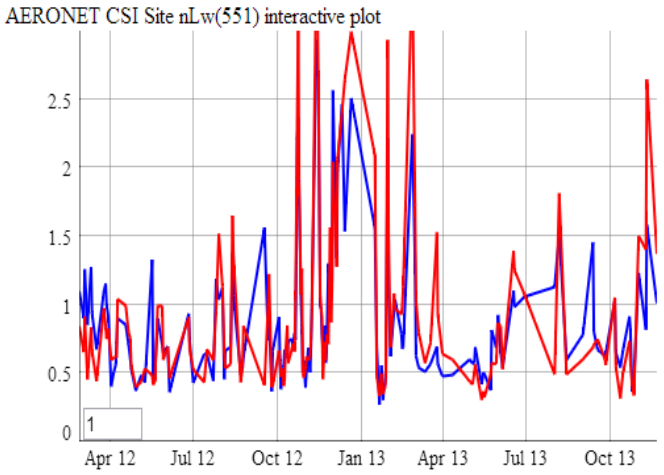
VIIRS ocean color products reached **Beta** status in January 2013, and plan to reach **Provisional** status in summer 2014.

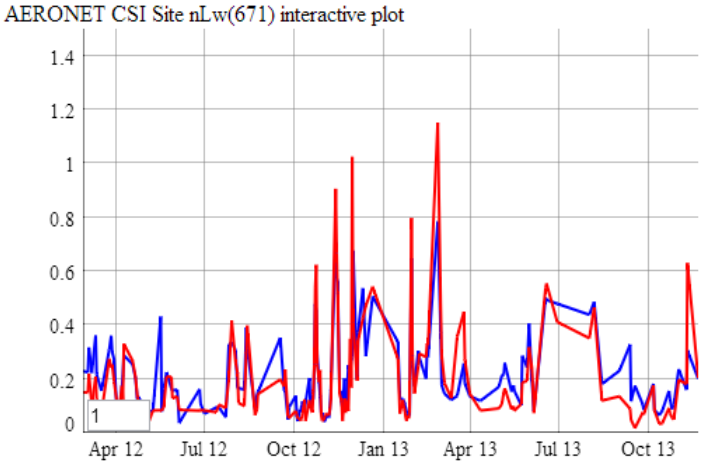
AERONET-CSI nL_w Time Series











In Situ

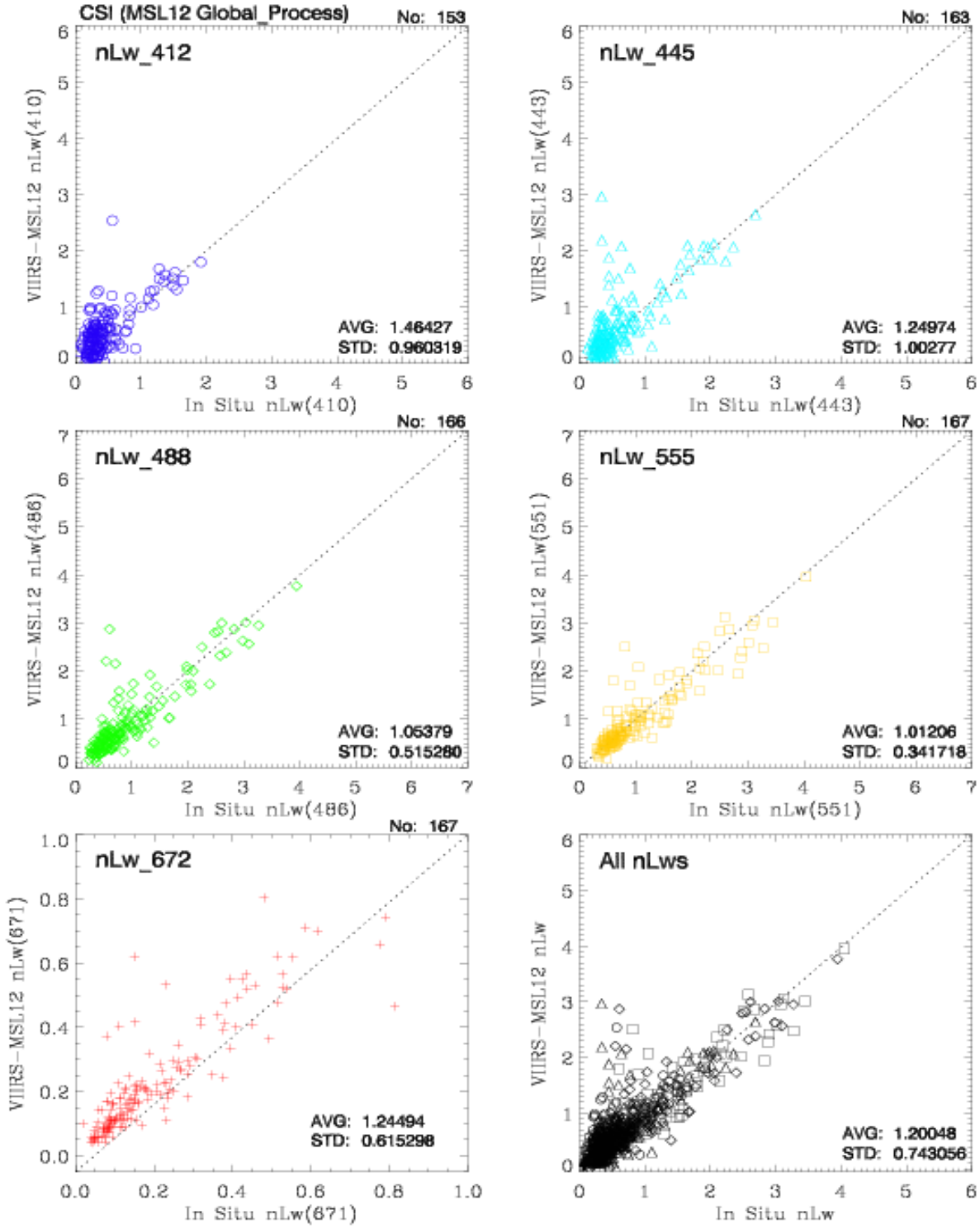
VIIRS (NOAA-MSL12)

AERONET-OC (CSI)

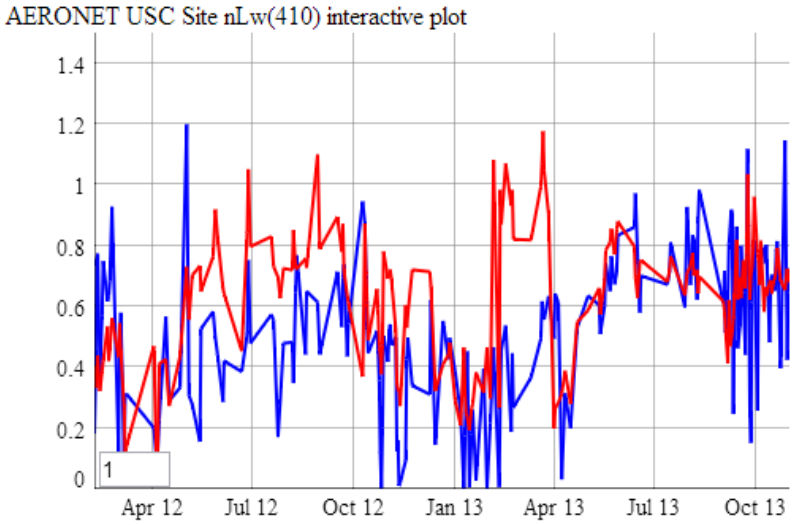
Matchup with

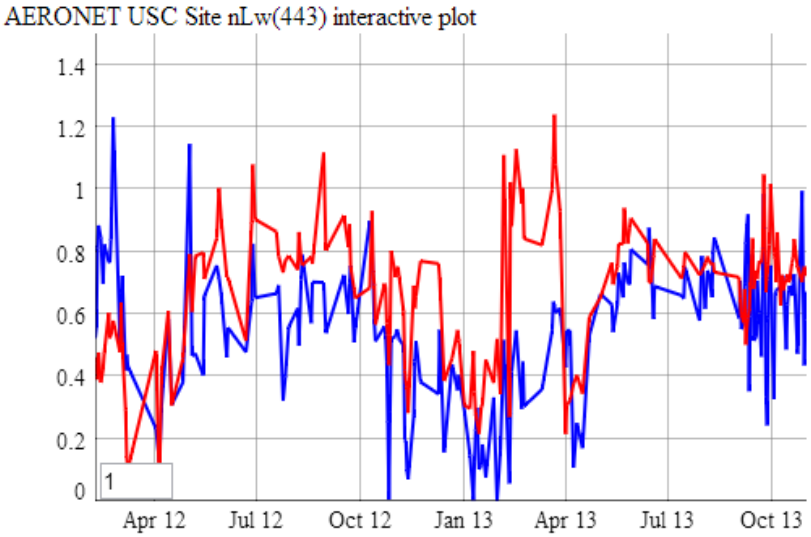
VIIRS

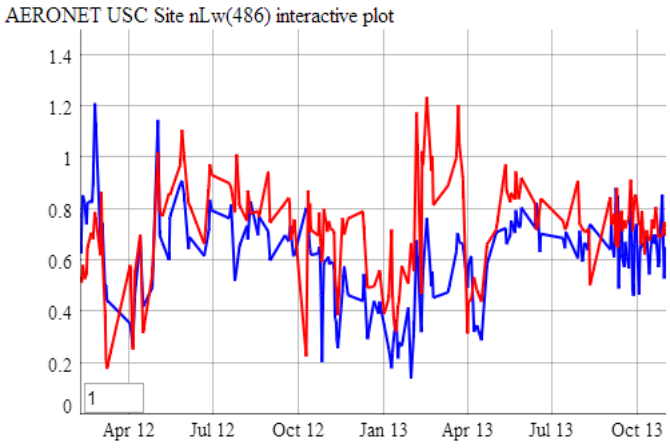
MSL12-Global

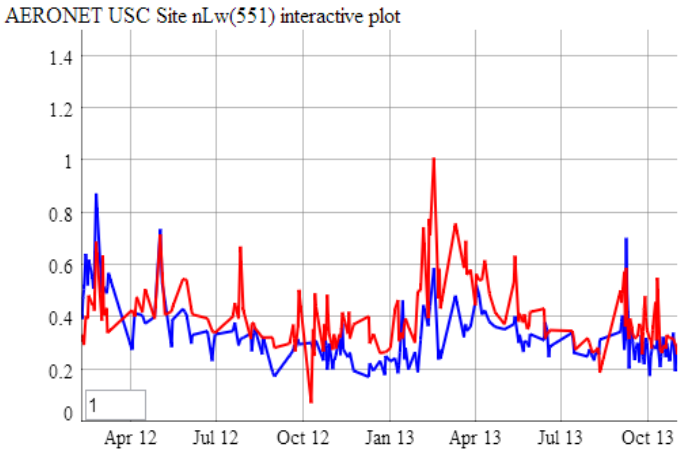


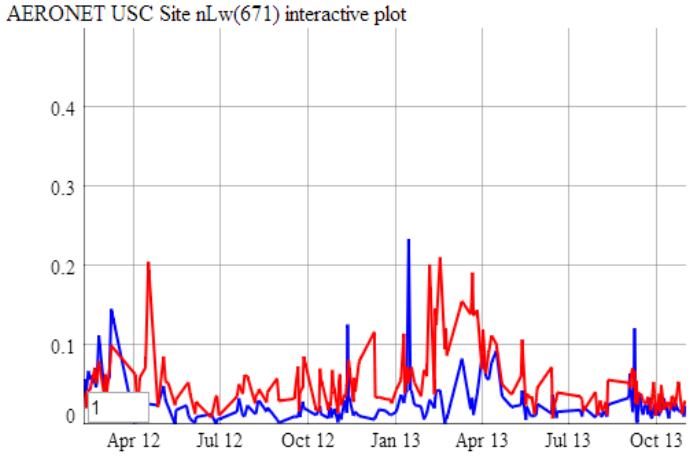
AERONET-USC nL_w Time Series











In Situ

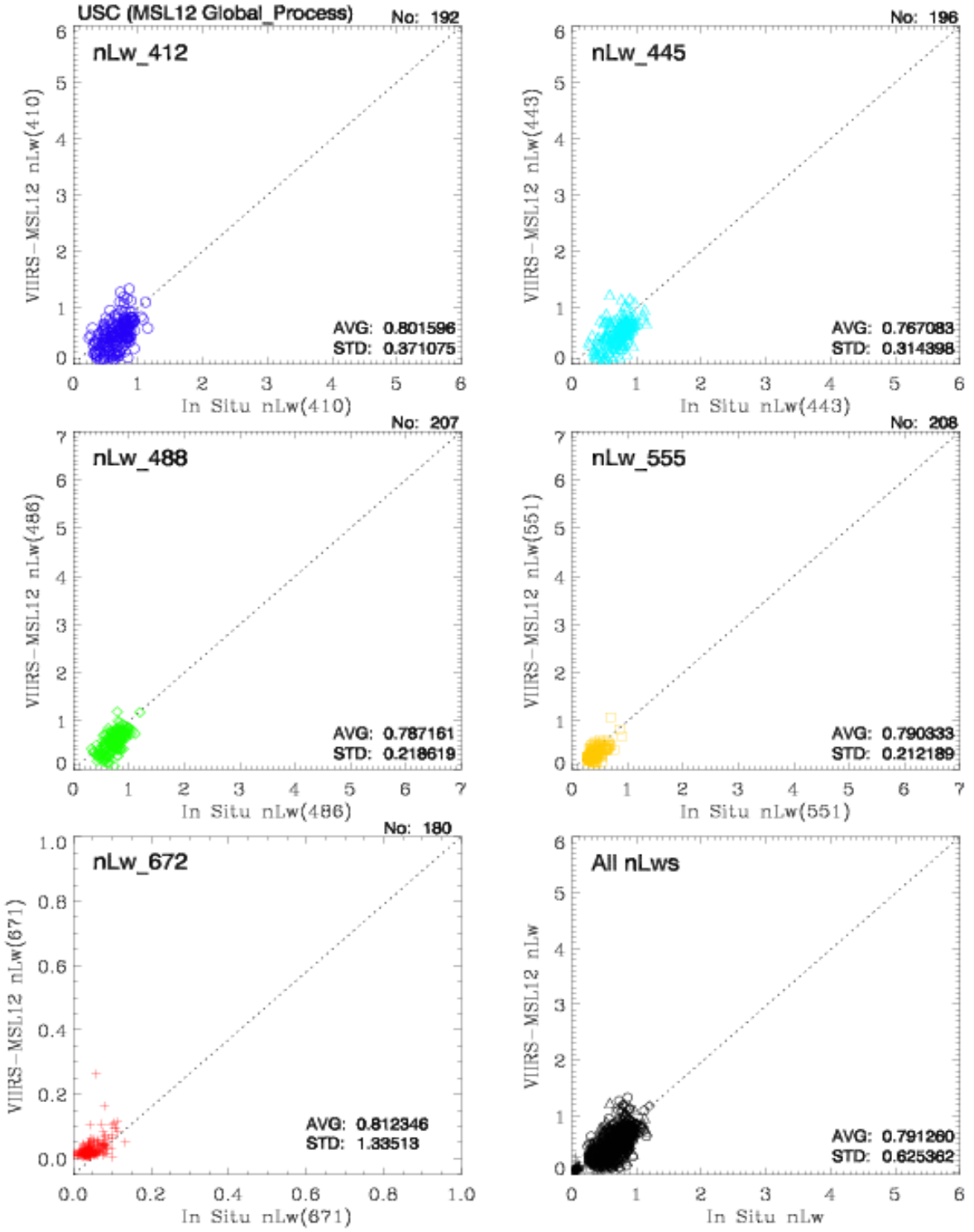
VIIRS (NOAA-MSL12)

AERONET-OC (USC)

Matchup with

VIIRS

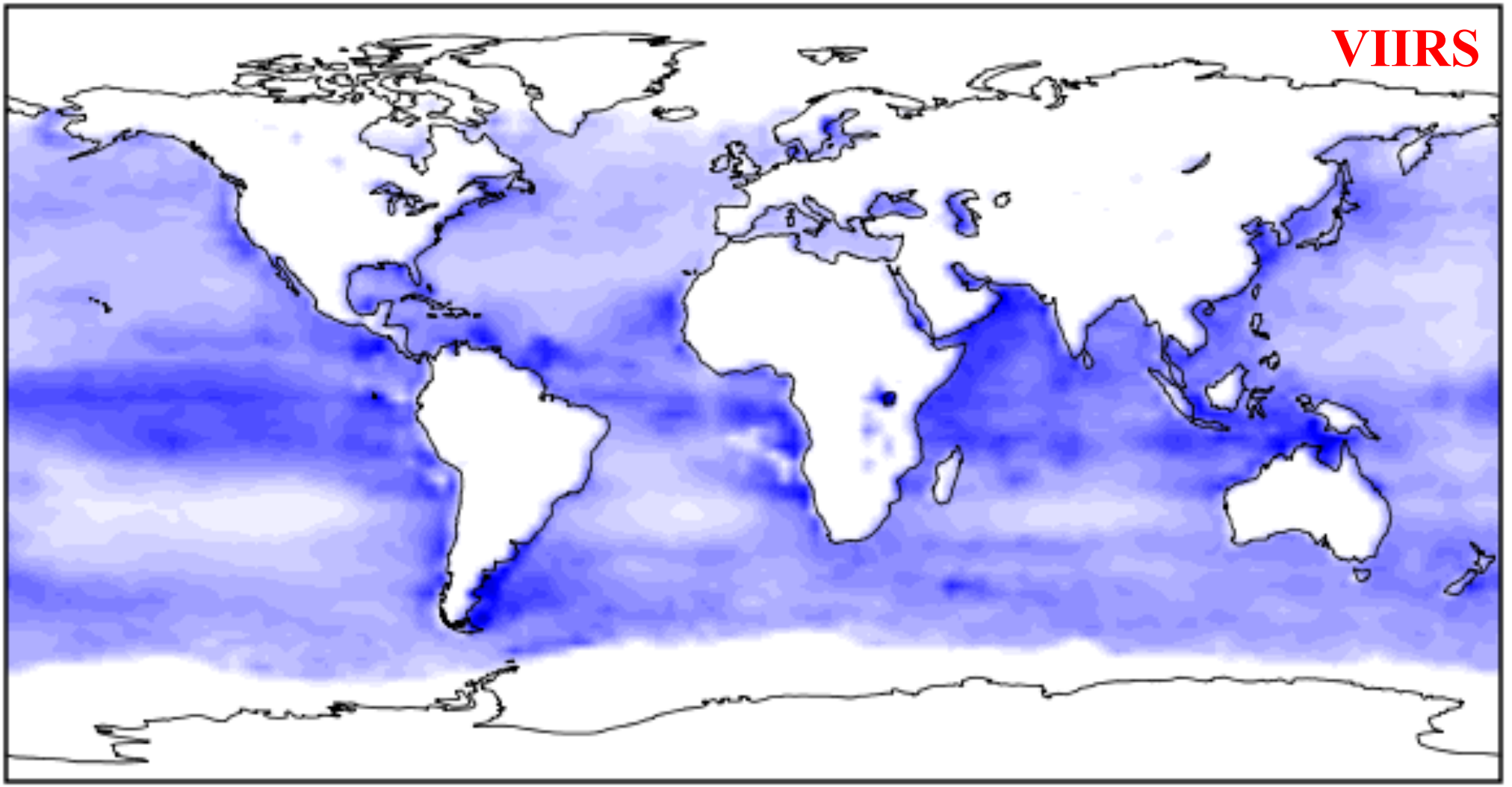
MSL12-Global



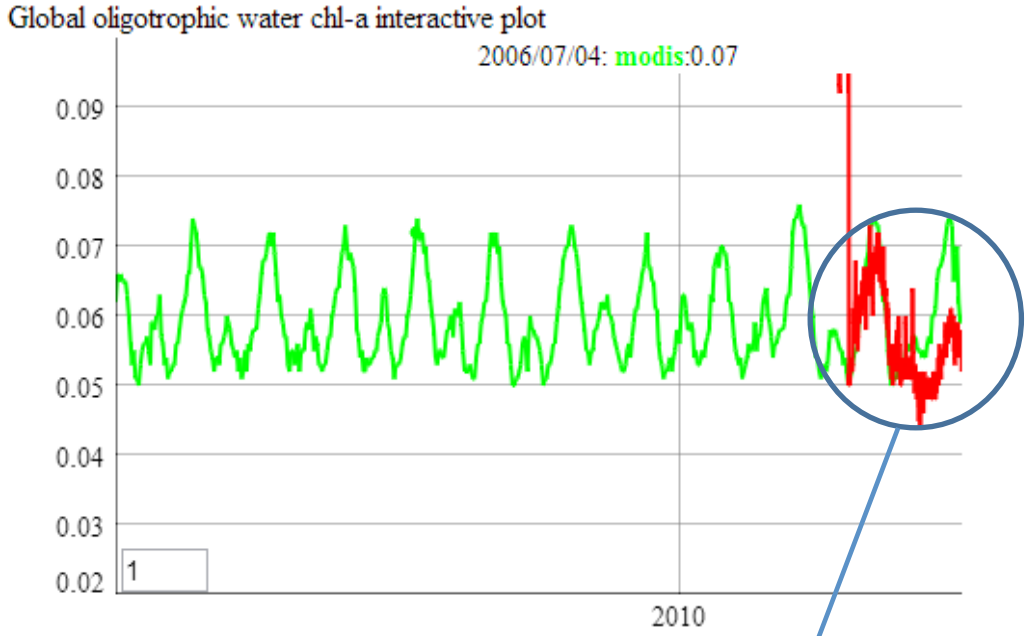
JPSS Proving Ground Project

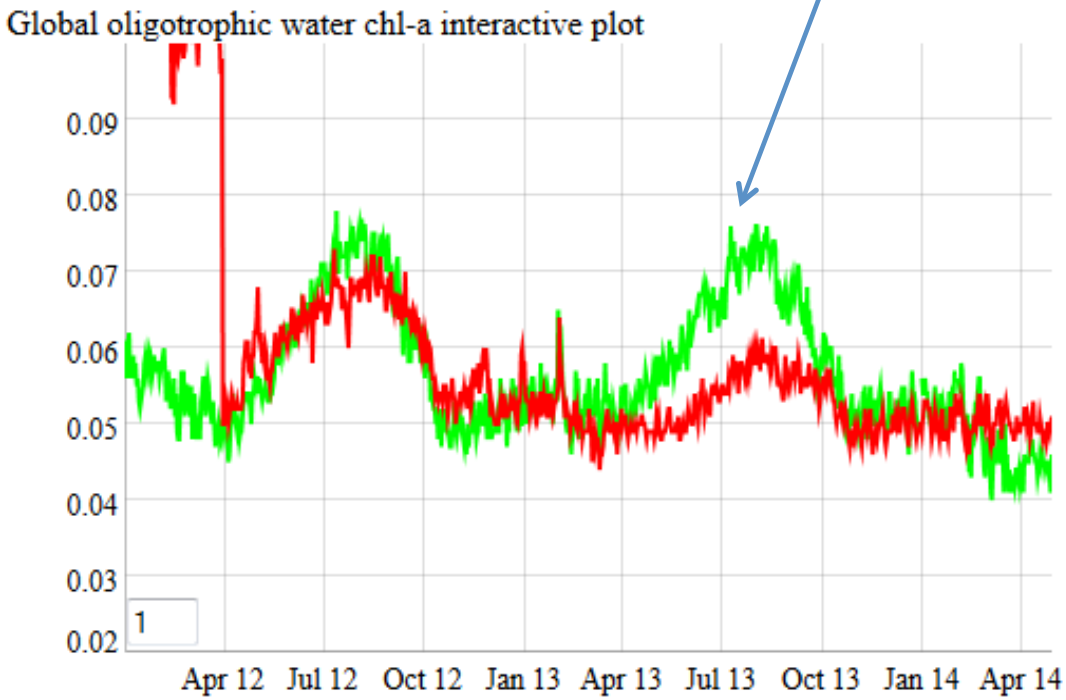
Global marine isoprene emissions (Tong *et al.*)

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



The Existing VIIRS Calibration Issue





MODIS-Aqua global oligotrophic water Chl-a from 2002 to 2013 (green), overplotted with VIIRS data from 2012 to 2013 (red)

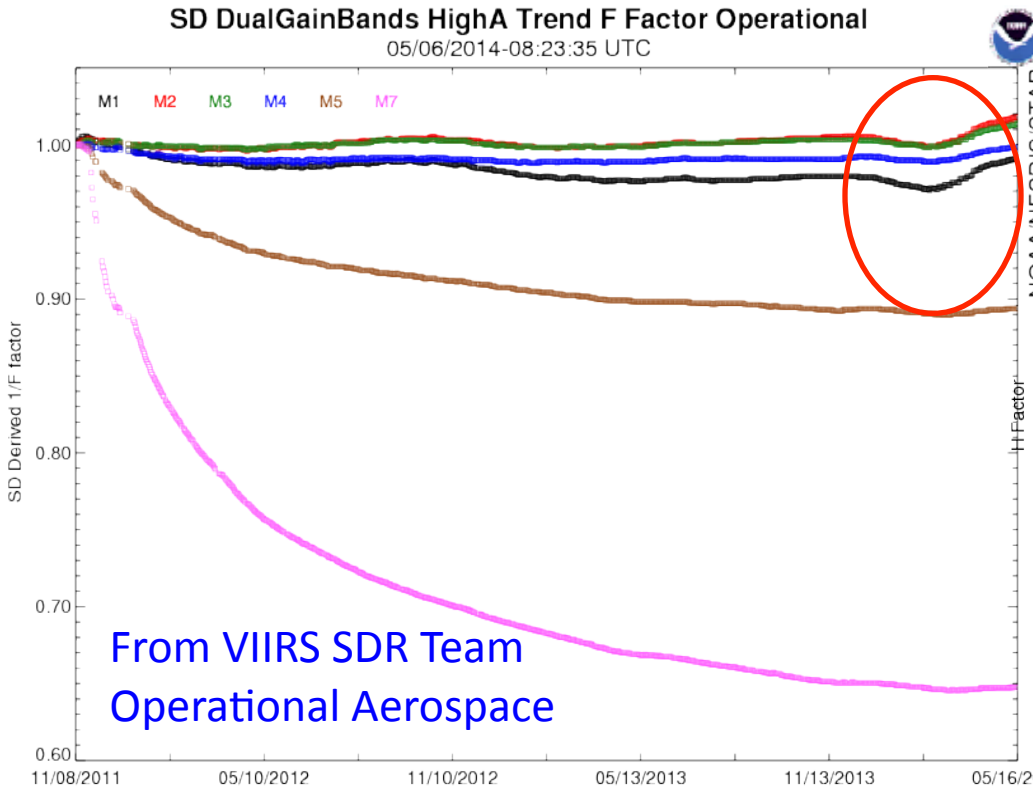
—— MODIS-Aqua

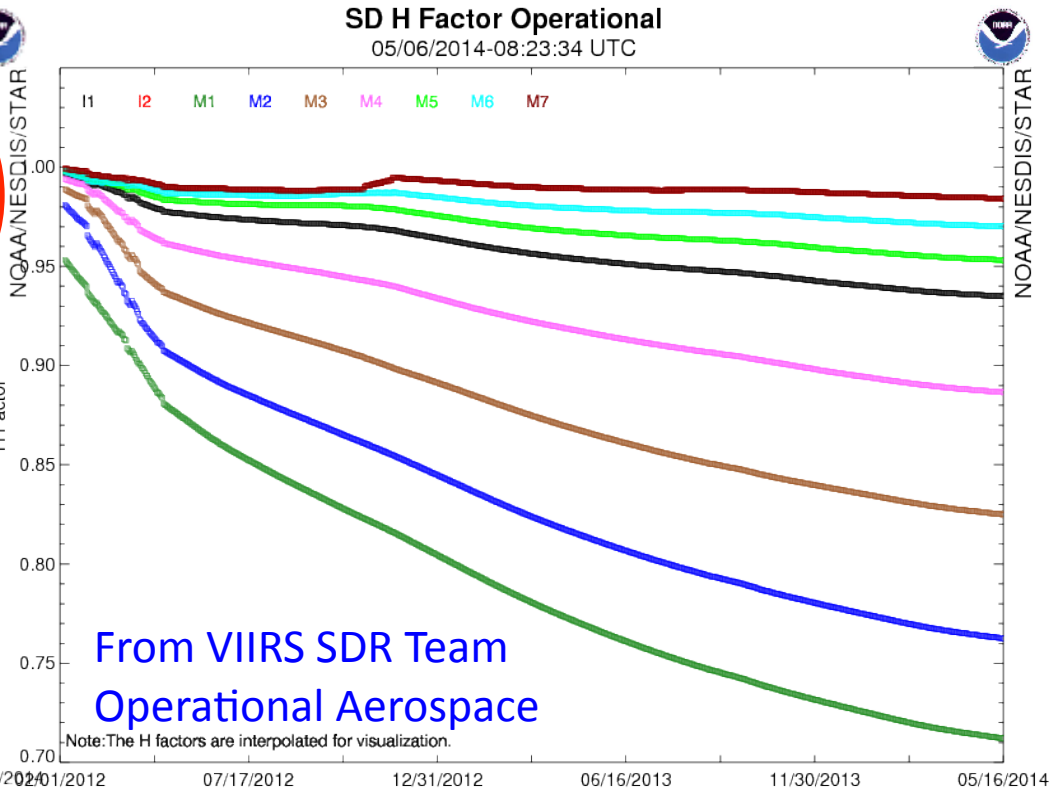
—— VIIRS (NOAA-MSL12)

- VIIRS and MODIS-Aqua match each other quite well in 2012.
- They have noticeable difference in 2013 (biased low from VIIRS).
- Since MODIS-Aqua has a reasonable Chl-a annual repeatability, It is confirmed that VIIRS SDR has calibration issues, in particular, for the M4 (551 nm) band (**biased low**), at least for 2013.

Recent Operational RSB H&F Factors Trends

(More detail this afternoon)



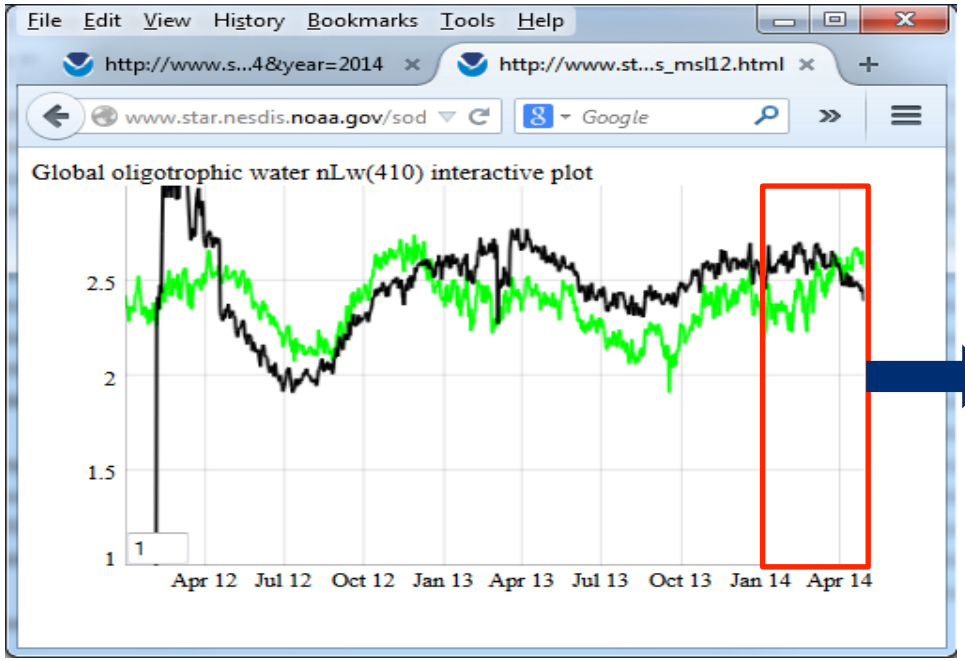


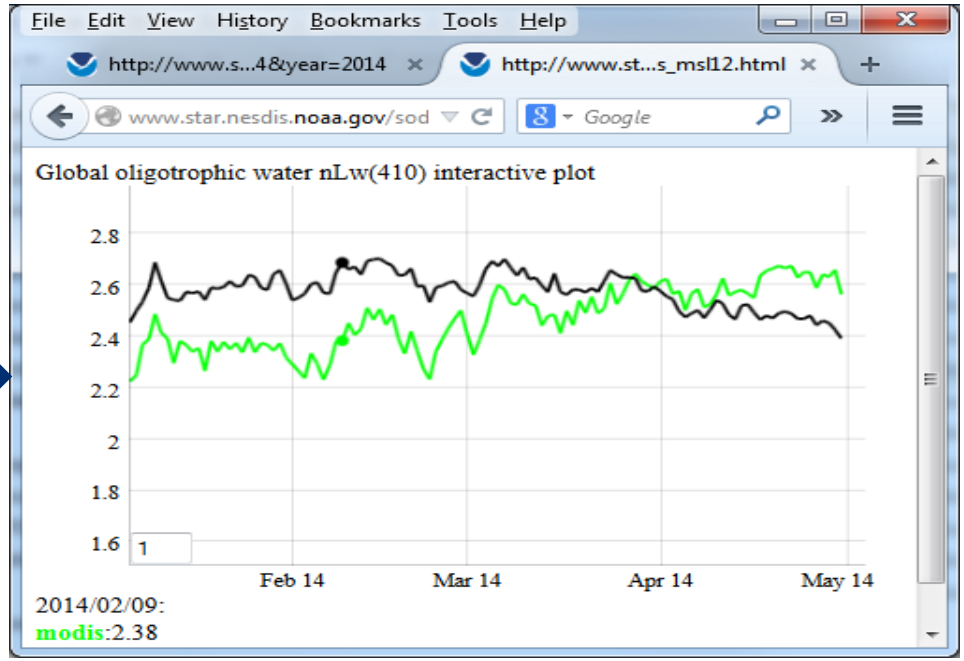
- Recent F-factors (1/F) show significant trend change which suggests that degradation has stopped or even reversed.
- F-lookup tables (1/F) for M1-M4 show significant increase of ~1-2% since early February. F factors for M1 and M2 increased ~2% in 3 months.
- Thus, calibration gains (TOA radiances) are decreased by ~2% for M1 and M2.

Quantitative Evaluation for Global Oligotrophic Waters

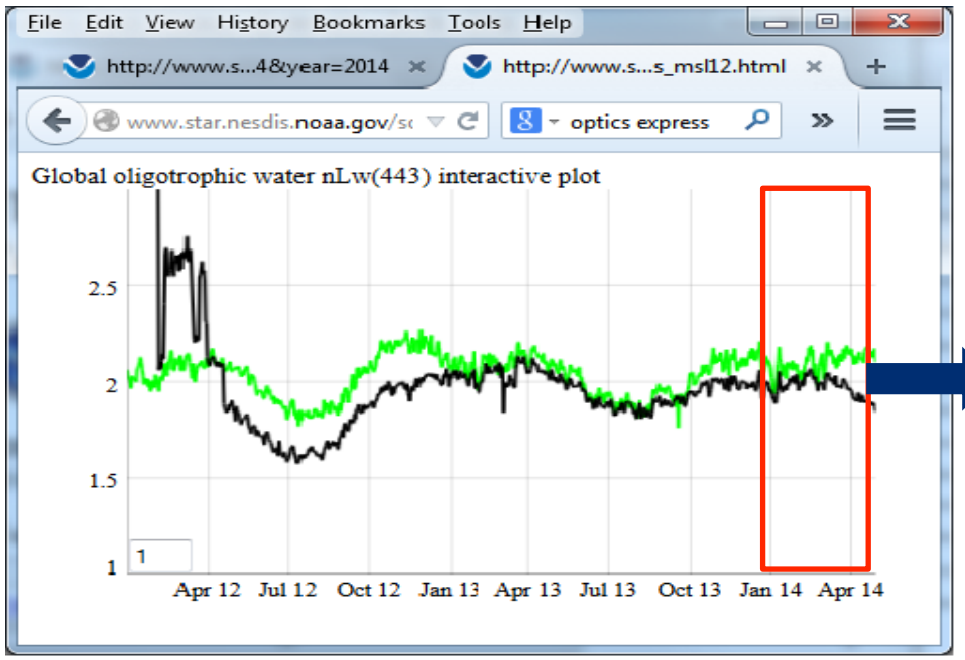
VIIRS MODIS-Aqua

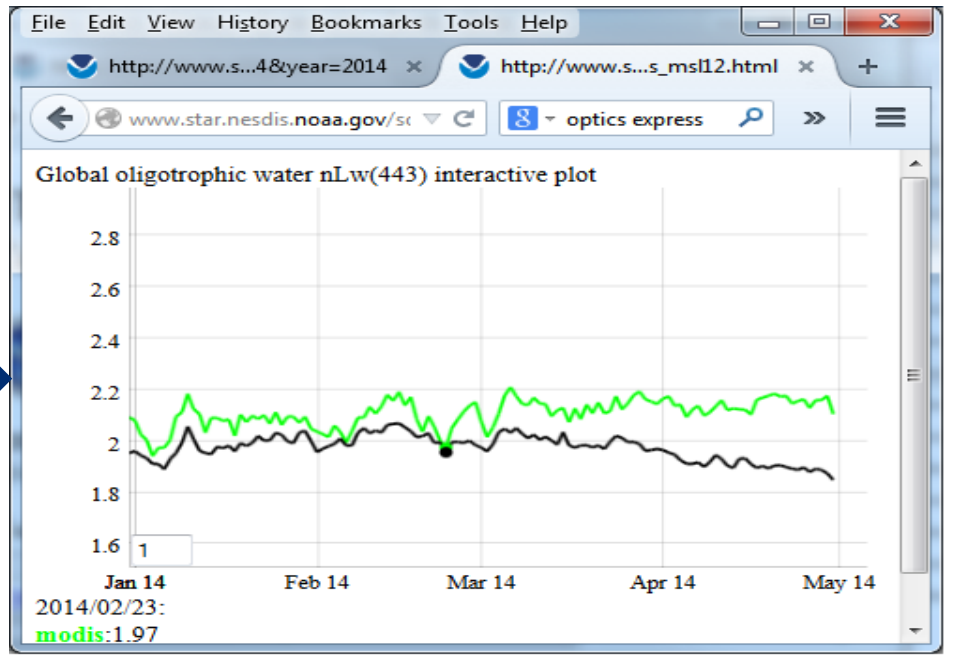
VIIRS vs. MODIS nLw(412)





VIIRS vs. MODIS nLw(443)





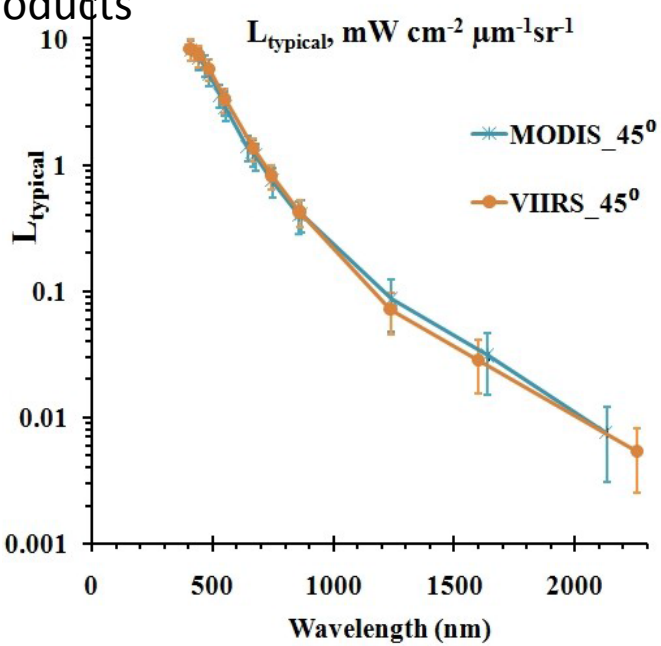
Some Selected Results from Various

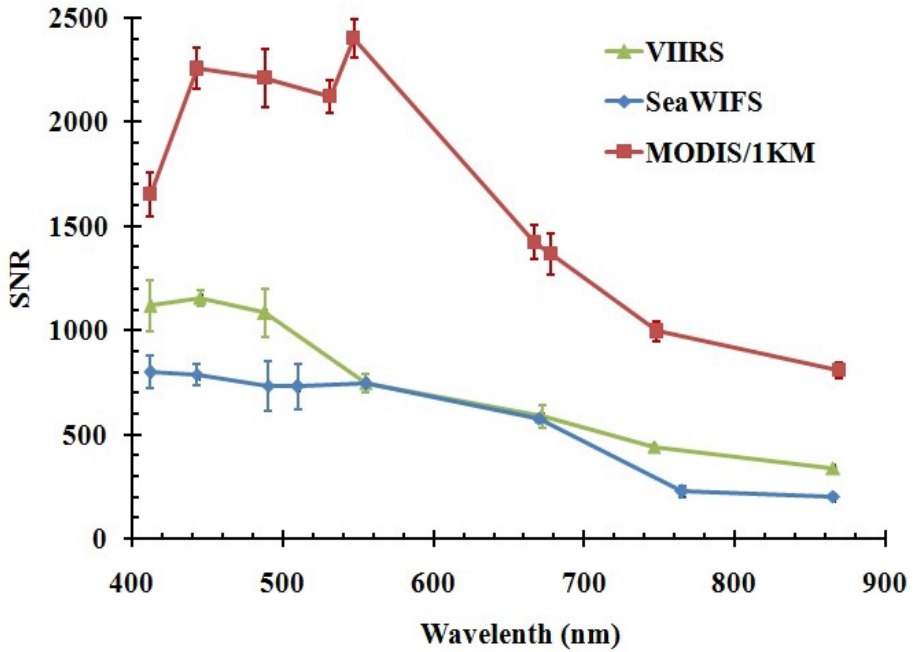
OC Cal/Val Team PIs

Chuanmin Hu/U. South Florida

- Project Objectives:
  - Evaluate VIIRS general performance (SNR, product noise)
  - Evaluate VIIRS IDPS data products for coastal waters
- Project Accomplishments:

VIIRS SNR(NIR) > SeaWiFS but < MODIS. Therefore, VIIRS Rrs and Chl data products should have less speckle noise than SeaWiFS. Is this true? We are evaluating these products

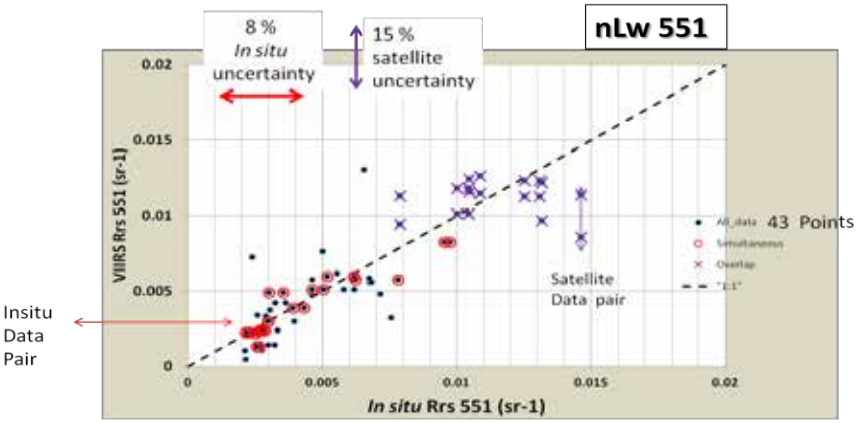




$L_{typical}$ and SNR calculated from measurements using approaches of Hu et al. (2012, Applied Optics).

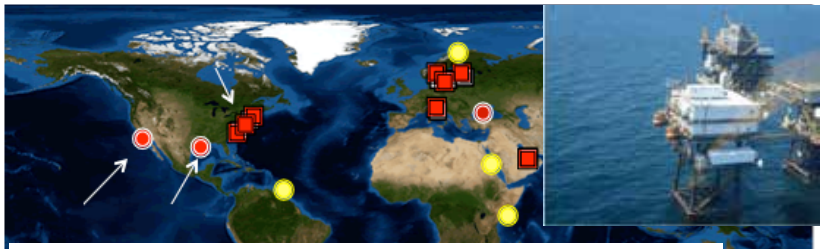
Stennis Group (USM, NRL, QNA, SDSU)

Arnone, Vandermeulen, Ladner, Fargion, Bowers, Crout, Martinolich

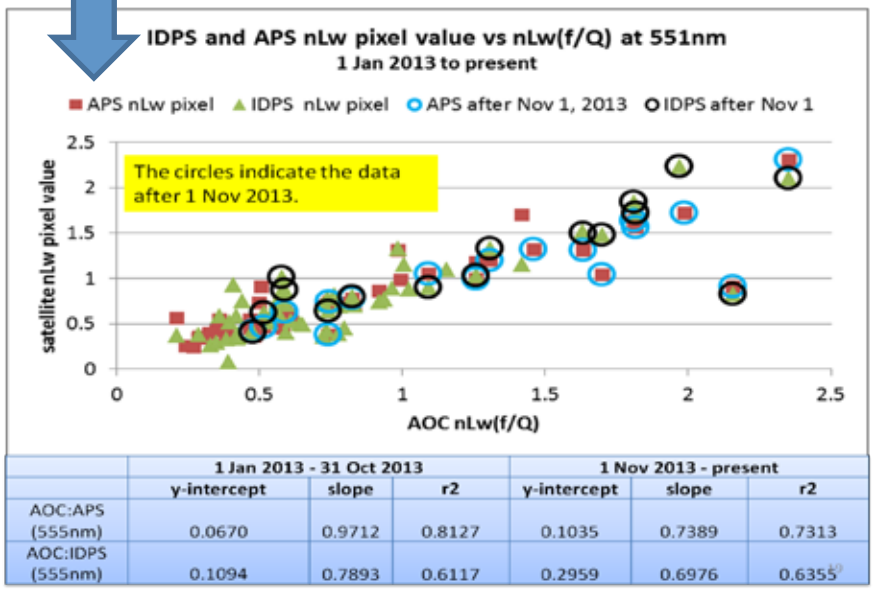


Defined the Uncertainty of sensor and in situ data

Tracking VIIRS Consistency in performance

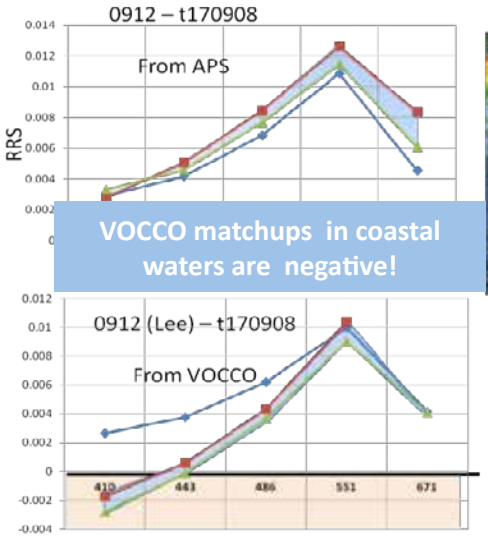


AERONET WavCIS, Gulf of Mexico

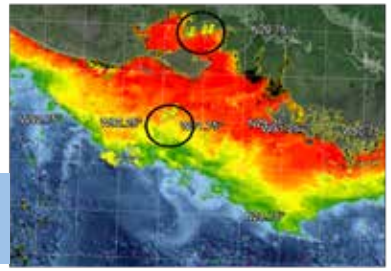


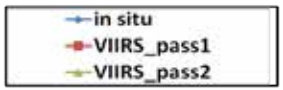
	1 Jan 2013 - 31 Oct 2013			1 Nov 2013 - present		
	y-intercept	slope	r2	y-intercept	slope	r2
AOC:APS (555nm)	0.0670	0.9712	0.8127	0.1035	0.7389	0.7313
AOC:IDPS (555nm)	0.1094	0.7893	0.6117	0.2959	0.6976	0.6355

Orbital Overlap within 100 minutes applied to VIIRS



VOCCO matchups in coastal waters are negative!





Multiple data sets show VOCCO can be improved in coastal waters.

VIIRS sensor is good for coastal products.
NIR processing required for Coastal waters.

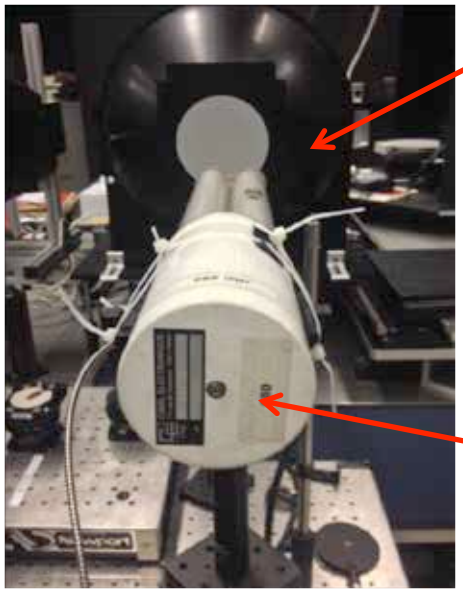
Plans to examine the detectors' impact on Validation

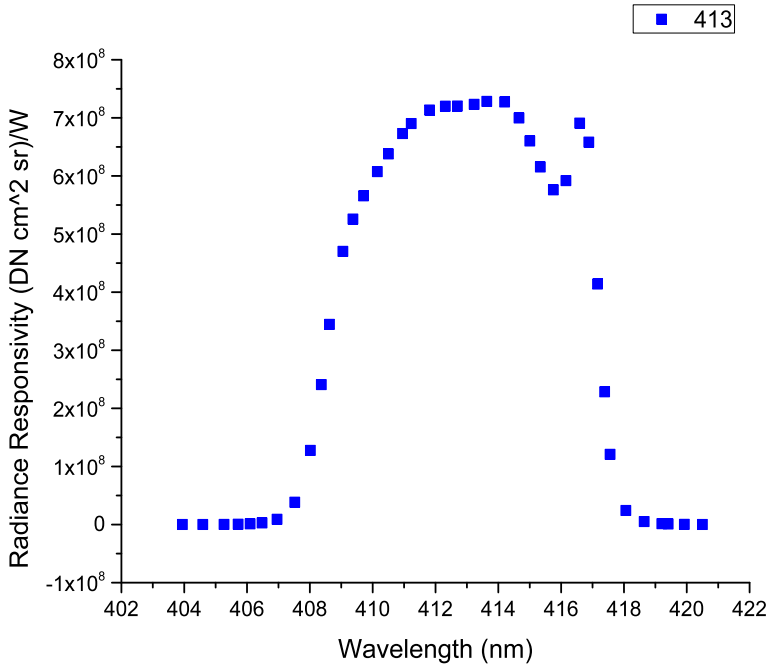
Established users of VIIRS Ocean Color products:

- Used for Science University and NASA research
- Navy Applications and transitions to operations
- Oil Spill research
- Ocean Weather Laboratory - USM
- NOAA - Fisheries

Carol Johnson/NIST

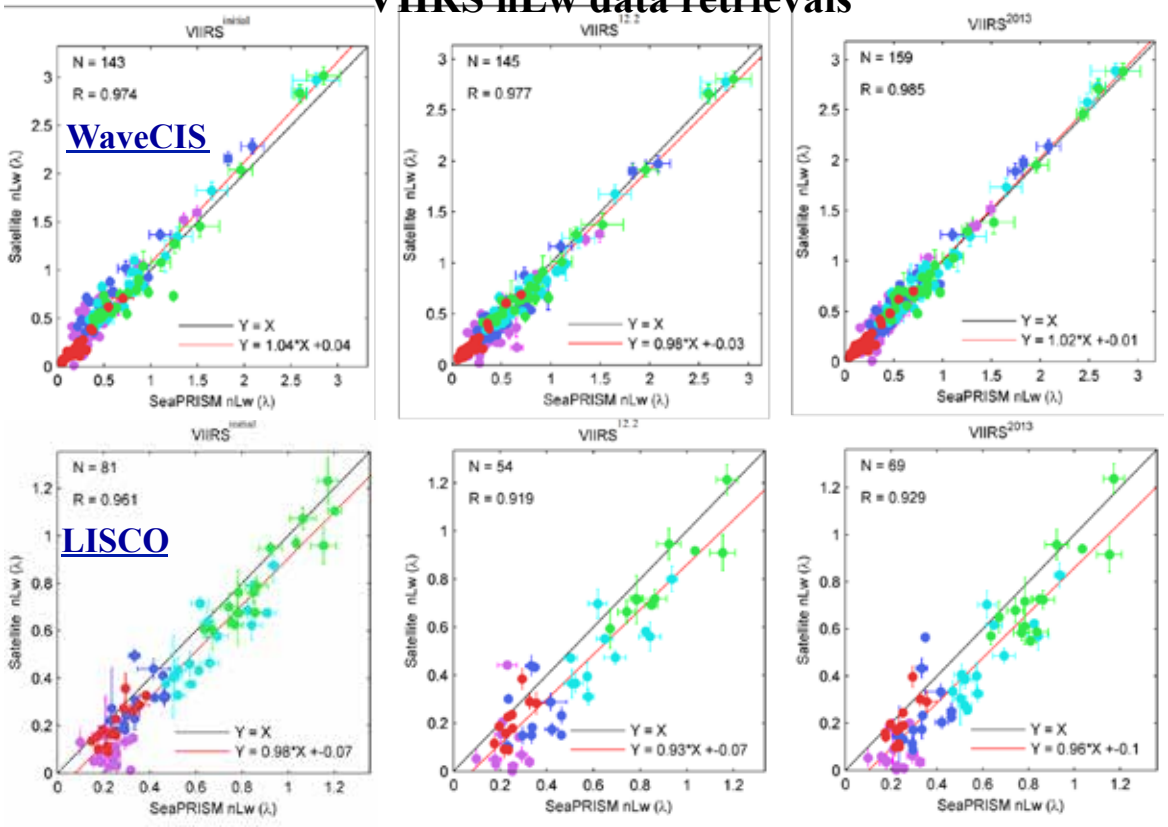
- Project Objectives:
  - Characterize and calibrate a SeaPRISM for absolute radiance responsivity for several ocean color channels and compare to calibration coefficients from broadband sources (NASA/GSFC and JRC/Italy)



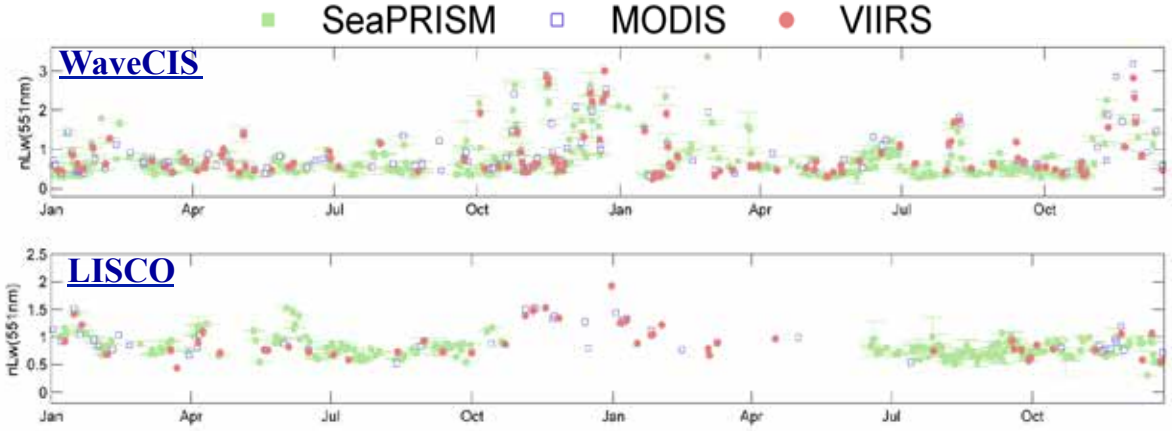


City College of New York - NOAA CREST

Evaluations of the impacts of processing schemes on VIIRS nLw data retrievals



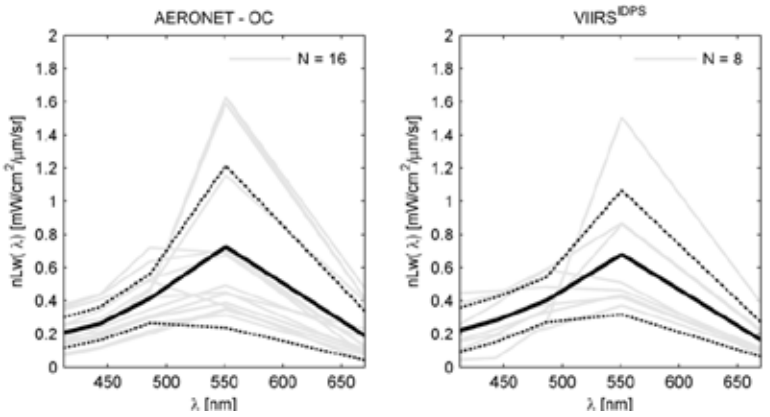
Time series of normalized water-leaving radiance, nLw(λ)



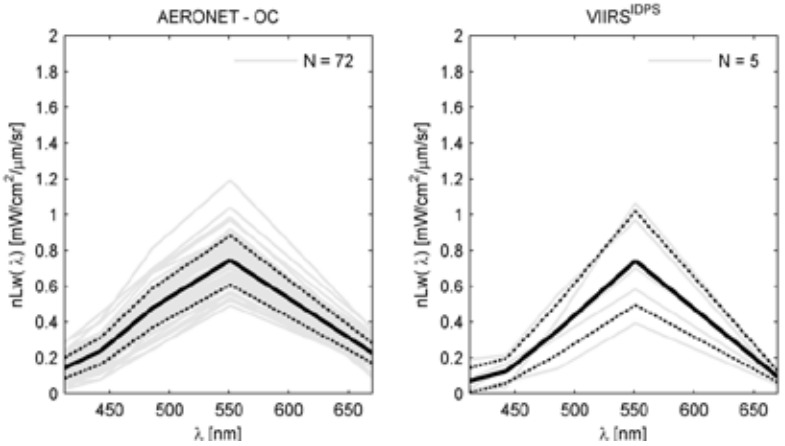
nLw(λ) match-up spectra of AERONET-OC and VIIRS^{IDPS} (with vicarious gains applied)

for June 17th to September 15th of 2013 period.

WaveCIS AERONET-OC site of gulf of Mexico

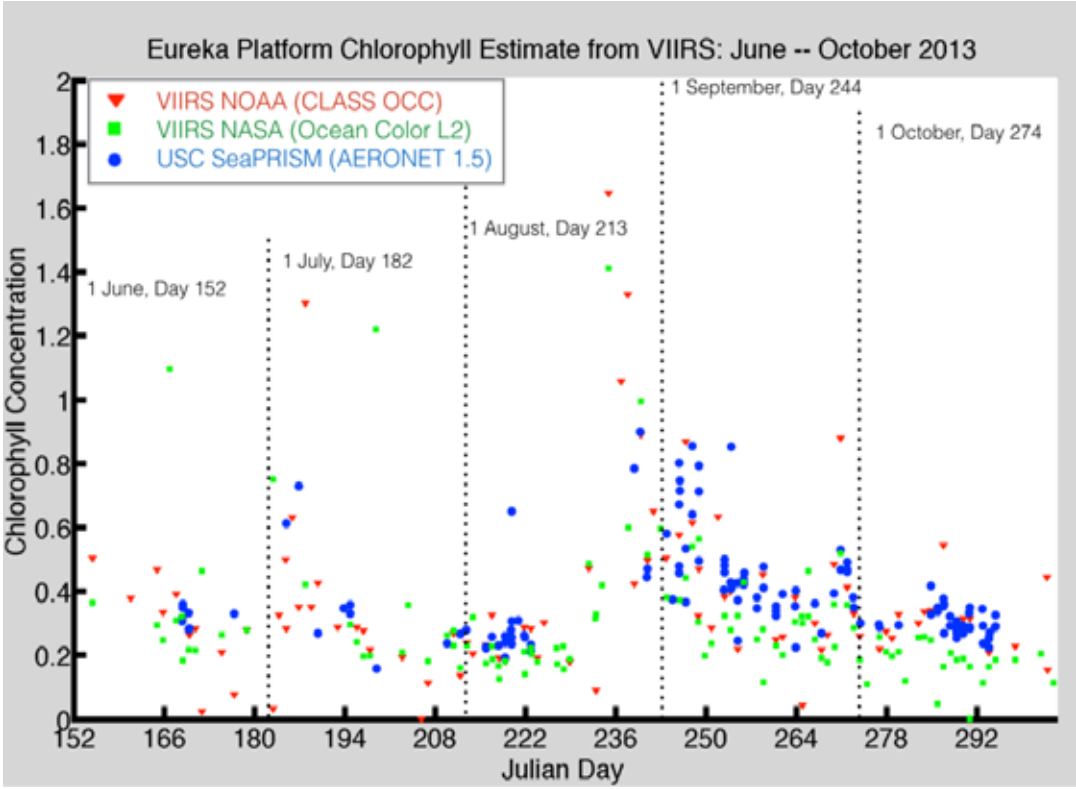


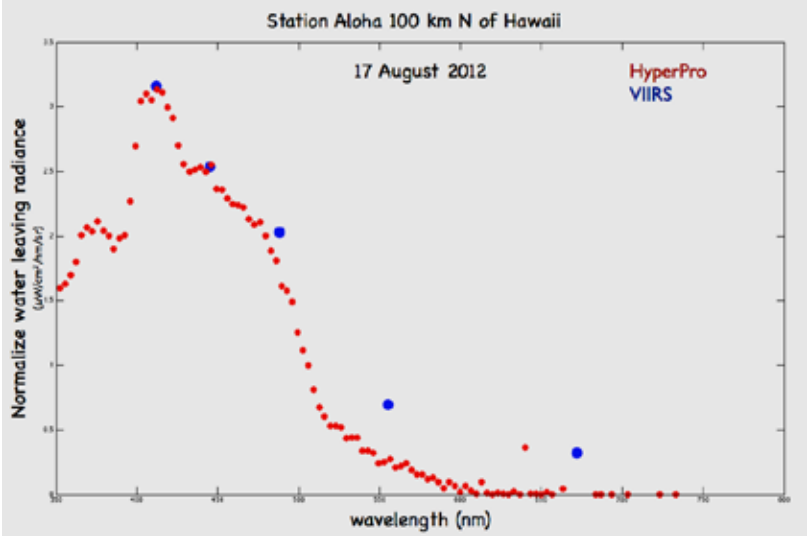
LISCO AERONET-OC site of Long Island Soun

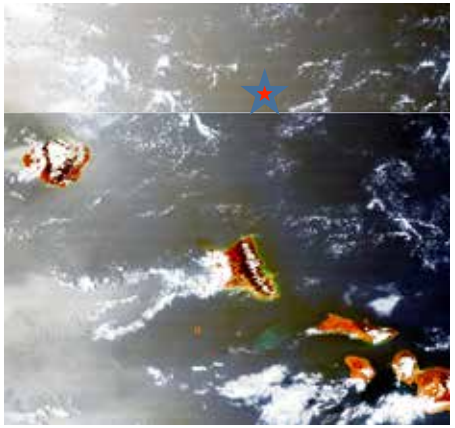


Ocean Color EDR Cal Val Team
OSU (C. Davis, N. Tufillaro and J. Nahorniak)

- Project Goal: Validate VIIRS ocean color data for Coastal (Platform Eureka, CA SeaPRISM data) and Open Ocean (Hawaiian Ocean Time series (HOT HyperPRO data) to validate NOAA, Navy and NASA ocean color products.
- Completing second year of matchups.





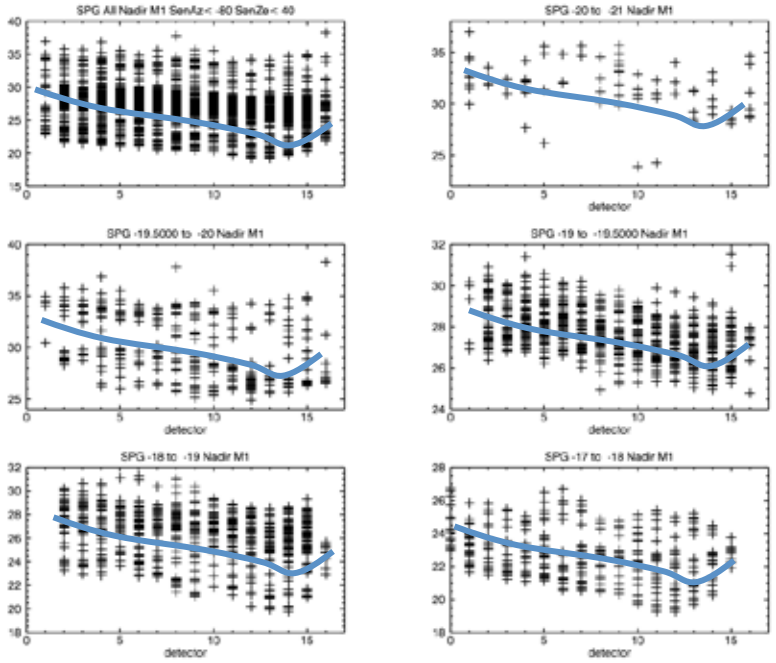


VIIRS image over Hawaii from 17 August 2012 (23:43 GMT). The star marks Station ALOHA.

Northrop Grumman Aerospace Systems

- Project Objectives:
  - A - Support ocean color calibration (sensor and/or algorithm artifacts and characterization)
    - Verify polarization sensitivity/characterize detector dependence (in progress)
  - B –support in-situ field work with OMT (sample from Antarctic)

nLw vs detector 412 nm



Conclusions

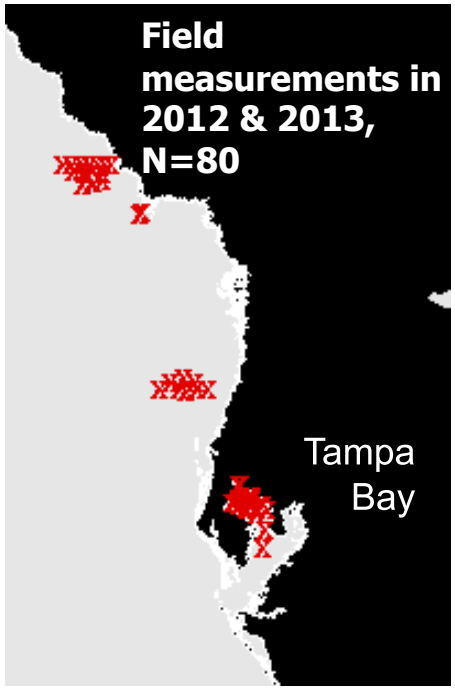
- In general, VIIRS OC normalize water-leaving radiance spectra show reasonable agreements with in situ measurements at MOBY, AERONET-OC sites, and various other ocean regions.
- In global deep waters and oligotrophic waters, the VIIRS ocean color products generated from NOAA-MSL12 were consistent with MODIS-Aqua in 2012, but discrepancy started to become noticeable for IDPS and MSL12 Chl-a data since early 2013. We confirmed that this is a VIIRS calibration problem in 2013.
- Since later 2013 (about Oct-Nov.), VIIRS Chl-a data from MSL12 are consistent with those from MODIS-Aqua, but there are noticeable differences since Feb. of 2014.
- Following the reverse trends of VIIRS SDR F-LUTs, global VIIRS nL_w data show decreasing trends from February to May of 2014. Using MODIS-Aqua as reference, nL_w(410) (M1) and nL_w(443) (M2) drifted lower ~**15-20**% as of early May 2014, and nL_w(488) (M3) decreased ~**8-10**% for global oligotrophic waters. The nL_w trends are continuing, and the correct F-LUTs should be used now!
- Although the OC EDR product quality is still not optimal, incremental product improvements have been made, and are occurring. With our efforts, VIIRS can provide high quality ocean color products.

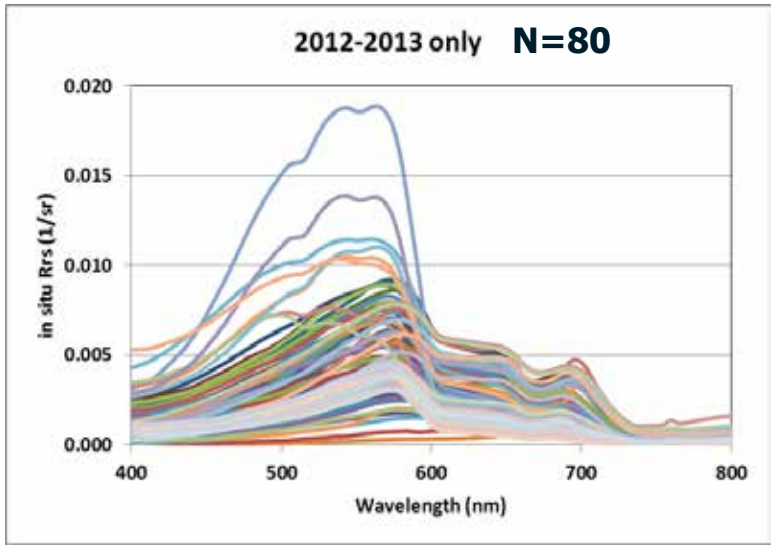
Some Backup Slides

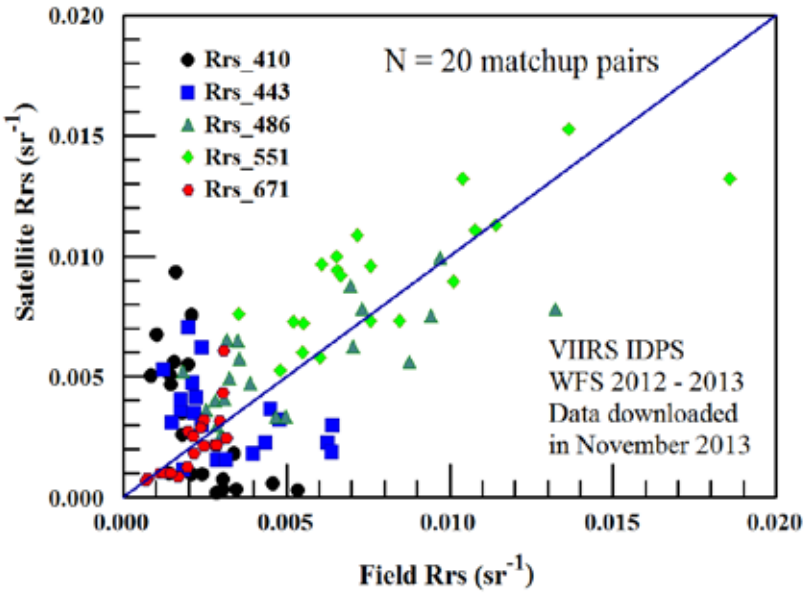
Thank You!

Some Additional Results from the **OC Team PIs** shown in following slides

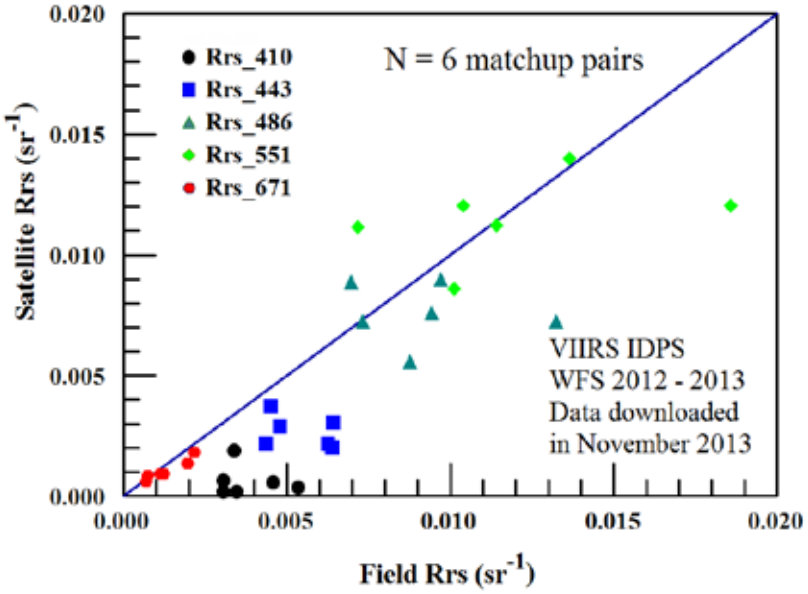
Chuanmin Hu/U. South Florida







No QC flags applied



QC flags applied

Stennis Group (USM, NRL, QNA, SDSU)

Arnone, Vandermeulen, Ladner, Fargion, Bowers, Crout, Martinolich

Project Objectives: VIIRS Cal Val – ocean EDR products - nLw, Chlor_a, and IOP's

Evaluate color product performance for operational use and science applications

Validate products in open and coastal waters

Recommend updates to VOCCO processing and algorithms

Recommendations to SDR team on impact to Ocean Color EDR

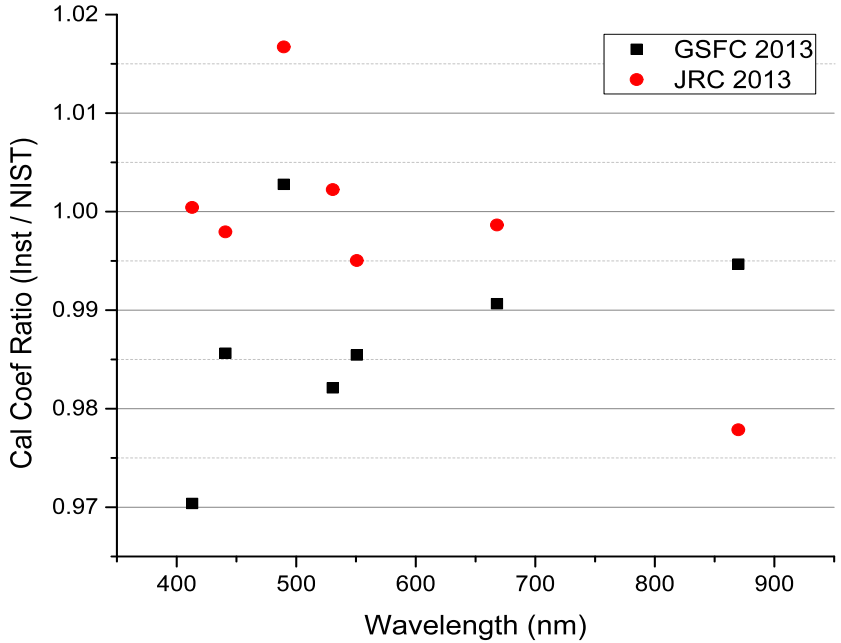
Project Accomplishments: Past year

1. Tracked VIIRS performance at MOBY and WAVCIS AERONET Site - established VIIRS gains
2. Participated in 5 field exercises to validate VIIRS products with NASA, NOAA, Navy and Universities:

   1) NOAA - Fisheries Cruise, 2) NASA GEOCAPE, 3) Navy - OCOLOR, 4) USM Gliders, 5) NOAA - Chesapeake Bay
3. Established IDPS limitations in coastal waters
4. Demonstrated successful coastal processing of VIIRS sensor using Navy's processing system
5. Recommended Coastal NIR algorithms for IDPS to improve coastal products for operations
6. Demonstrated use of the VIIRS orbital overlap for sensor validation
7. Defined VIIRS matchup methods for characterizing uncertainty from detector, sensor and in-situ data
8. Evaluated the VIIRS flags for use in match-up masks
9. Evaluated the M and I bands for Ocean Color products
10. Stennis presented 6 presentations to the cal/val team.
11. Outreach: 8 papers and presentations on successful VIIRS ocean color products
12. Established a user community (University, Navy and NMFS)

Carol Johnson/NIST

- Project Accomplishments:
  - Custom interface to filter wheel/radiometer head
  - Data acquisition software necessary to interface to SIRCUS
  - Empirical model developed to explain observed discrepancies in values and nonlinearities – involves behavior of background counts in this interface mode
  - Preliminary results are in good agreement with GSFC and JRC



City College of New York - NOAA CREST

- Project Objectives:
  - To monitor the validity of the VIIRS^{IDPS} ocean color products for coastal waters.
  - To evaluate the consistency of the VIIRS processing and cal/val schemes.

- **Science accomplishments**

✓ Quality of VIIRS's OC data retrievals (*nLw* and atmospheric parameters) for different processing schemes (gain sets) are analyzed based on comparison with AERONET-OC and MODIS data. (Remote Sensing of Environment, December 2013)

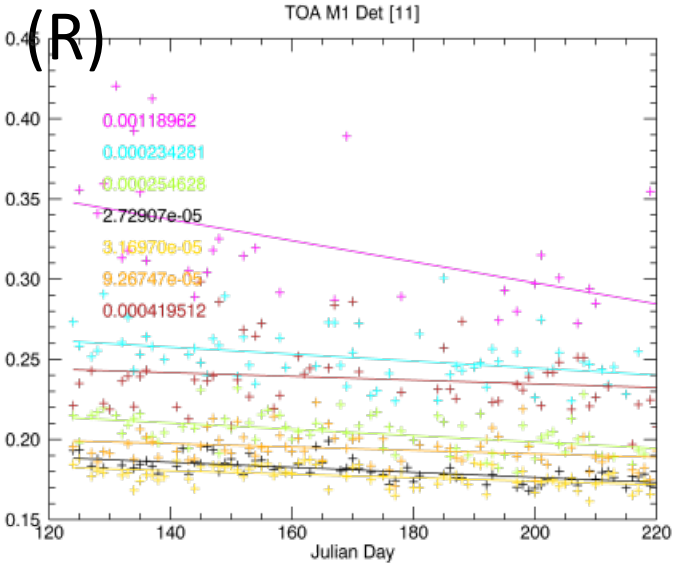
✓ A novel radiative transfer based OC satellite sensor vicarious cal/val approach has been developed. This approach has been shown to be very promising and gains of the VIIRS and MODIS sensors are derived with data from both the LISCO and WaveCIS AERONET-OC sites.(A paper is in preparation for submission to a peer-reviewed journal).

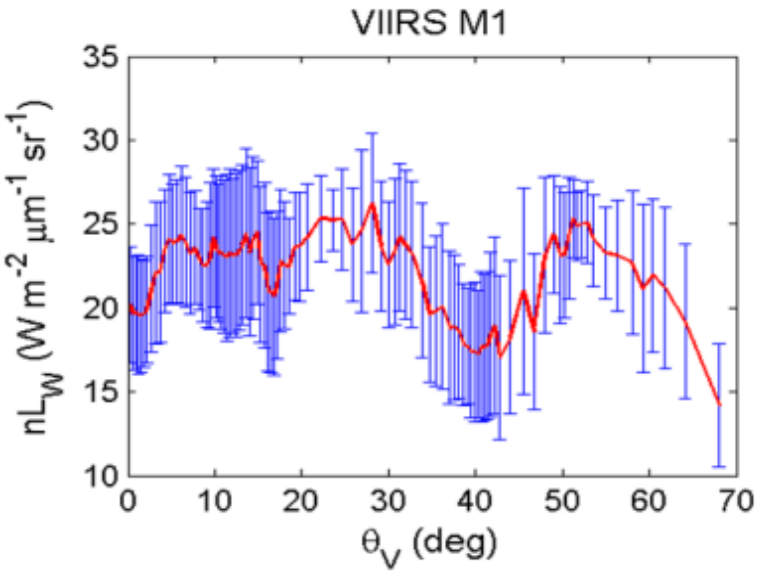
- **Publications**

1. S. Hlaing, T. Harmel, A. Gilerson, R. Foster, A. Weidemann, R. Arnone, M. Wang, S. Ahmed, "Evaluation of the VIIRS ocean color monitoring performance in coastal regions, " **Remote Sensing of Environment, "139, 398–414, 2013**.
2. S. Ahmed, A. Gilerson, S. Hlaing, A. Weidemann, R. Arnone, M. Wang, "Evaluation of ocean color data processing schemes for VIIRS sensor using in-situ data of coastal AERONET-OC sites," Proceeding of SPIE 8888, Remote Sensing of the Ocean, Sea Ice, Coastal Waters, and Large Water Regions 2013, 88880H (October 16, 2013); doi:10.1117/12.2028821.
3. S. Ahmed, A. Gilerson, S. Hlaing, I. Ioannou, M. Wang , A. Weidemann, R. Arnone, "Evaluation of VIIRS ocean color data using measurements from the AERONET-OC sites," Proceeding of SPIE 8724, Ocean Sensing and Monitoring V, 87240L (June 3, 2013); doi:10.1117/12.2017756.
4. S. Ahmed, A. Gilerson, S. Hlaing, A. Weidemann, R. Arnone, and M. Wang, "Assessments of VIIRS Ocean Color data retrieval performance in coastal regions", Proceeding of IOCS 2013 meeting, May 2013.

- **Presentations** (**1**) S. Ahmed, SPIE, Dresden, Germany, September, 2013. (**2**) IOCS 2013 meeting, Darmstadt, Germany, May 2013 (**3**) SPIE, Baltimore, Maryland, April, 2013. (**4**) S. Hlaing, AGU, Honolulu, Hawaii, March 2014

- Project Accomplishments:
  - A - identified scan dependency (verified by community) is apparent in trending (L) but not on daily times scales (R)





  - B – prepared DR7384 for sun-glint correction code update
  - C – supported DPE functional and regression testing of