VIIRS Ocean Color Team Activities in 2017

Menghua Wang &
Ocean Color EDR Team

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

STAR JPSS 2016 Annual Science Team Meeting
NCWCP, College Park, Maryland, August 14-18, 2017

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

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VIIRS Ocean Color EDR & Cal/Val Teams

EDR	Name	Organization	Funding Agency	Task
Lead	**Menghua Wang (OC EDR & Cal/Val Lead),** L. Jiang, X. Liu, W. Shi, S. Son, L. Tan, X. Wang, J. Sun, K. Mikelsons, M. Chu, V. Lance, **M. Ondrusek,** E. Stengel, C. Kovach	NOAA/NESDIS/ STAR	JPSS/NJO	Leads – Ocean Color EDR Team & Cal/Val Team OC products, algorithms, SDR, EDR, Cal/Val, vicarious cal., refinements, data processing, reprocessing, algorithm improvements, software updates, data validations and analyses
Ocean Color	**Robert Arnone** Sherwin Ladner, Adam Lawson, Jen Bowers	U. Southern MS, NRL, QinetiQ Corp., SDSU	JPSS/NJO	Satellite matchup tool (SAVANT) – Golden Regions, Cruise participation and support WAVE_CIS (AERONET-OC site) operation
	Carol Johnson	NIST	JPSS/NJO	Traceability, AERONET Uncertainty
	Nicholas Tufillaro, Curt Davis	OSU	JPSS/NJO	Ocean color validation, Cruise data matchup West Coast
	Burt Jones, Matthew Ragan	USC	JPSS/NJO	Eureka (AERONET Site)
	Alex Gilerson, **Sam Ahmed**	CUNY	JPSS/NJO	LISCO (AERONET site), Cruise data and matchup
	Chuanmin Hu	USF	JPSS/NJO	NOAA data continuity, OC data validation
	Ken Voss & **MOBY** team	Miami	JPSS/NJO	Marine Optical Buoy (MOBY)
	Zhongping Lee, Jianwei Wei	UMB	JPSS/NJO	Ocean color IOP data validation and evaluation Ocean color optics matchup

Working with: **NOAA CoastWatch**, VIIRS SDR team, DPA/DPE, Raytheon, NOAA OC Working Group, NOAA various line-office reps, NOAA NCEI, NOAA OCPOP, IOCCG, NASA, ESA, EUMETSAT, etc.

Collaborators: D. Antoine (BOUSSOLE), B. Holben (NASA-GSFC), G. Zibordi (JRC-Italy), R. Frouin (for PAR), and many others.

VIIRS Spectral Bands for Ocean Color

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

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

†VIIRS-SNPP nominal center wavelength

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

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Summary of VIIRS Ocean Color EDR Products

- **Inputs**:
  - VIIRS M1-M7, I1, and the **SWIR** M8, M10, and M11 bands SDR data
  - Terrain-corrected geo-location file
  - Ancillary meteorology and ozone data
- **Operational (Standard) Products** (9):
  - Normalized water-leaving radiance (nL_w's) at VIIRS visible bands M1-M5, and **I1 (638 nm)**
  - Chlorophyll-a (Chl-a) concentration
  - Diffuse attenuation coefficient for the downwelling spectral irradiance at the wavelength of 490 nm, $K_d(490)$
  - Diffuse attenuation coefficient of the downwelling photosynthetically available radiation (PAR), K_d(PAR)

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

- I
  - Inherent Optical Properties (IOP-a, IOP-a_{ph}, IOP-a_{dg}, IOP-b_b, IOP-b_{bp}) at VIIRS M2 or other visible bands (M1-M5) from the Quasi-Analytical Algorithm (QAA) (*Lee et al.*, 2002)
  - Photosynthetically Available Radiation (PAR) (*R. Frouin*)
  - Chl-a from ocean color index (OCI) method (*Hu et al.*, 2012; *Wang and Son*, 2016)
  - **QA Score** for data quality ($nL_w(\lambda)$ spectra) (*Wei et al.*, 2016)

We are open for adding new VIIRS global products

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

End-to-End Ocean Color Data Processing

- NOAA Ocean Color Team has been developing/building the capability for the **End-to-End** satellite ocean color data processing including:
  - Level-0 (or Raw Data Records (RDR)) to Level-1B (or Sensor Data Records (SDR)).
  - Level-1B (SDR) to ocean color Level-2 (Environmental Data Records (EDR) using the Multi-Sensor Level-1 to Level-2 (**MSL12**) ocean color data processing---**measurement-based data processing system**.
  - Level-2 to global Level-3 (routine daily, 8-day, monthly, and climatology data/images).
  - Validation of satellite ocean color products (in situ data and data analysis capability).
- Support of in situ data collections for VIIRS Cal/Val activities, e.g., **MOBY**, **AERONET-OC** sites (3 sites operation, added **Lake Erie site**), **NOAA dedicated Cal/Val cruises** (2014, 2015, **2016**, ….,)
- **On-orbit instrument calibration (solar and lunar) for ocean color data processing:**
  - J. Sun and M. Wang, "Radiometric calibration of the VIIRS reflective solar bands with robust characterizations and hybrid calibration coefficients," *Appl. Opt.*, **54**, 9331–9342, 2015.
- **On-orbit vicarious calibration using MOBY in situ data:**
  - M. Wang, W. Shi, L. Jiang, and K. Voss, "NIR- and SWIR-based on-orbit vicarious calibrations for satellite ocean color sensors," *Opt. Express*, **24**, 20437-20453, 2016.
- **RDR (Level-0) to SDR (Level-1B) data processing** (efficient RDR to SDR processing)**:**
  - Sun, J., M. Wang, L. Tan, and L. Jiang, "An efficient approach for VIIRS RDR to SDR data processing," *IEEE Geosci. Remote Sens. Lett.*, **11**, 2037–2041, 2014.
- **Ocean Color Viewer** (**OCView**)—Online display and monitoring of ocean color product imagery.
- **O**cean **C**olor **D**ata **A**nalysis and **P**rocessing **S**ystem (**OCDAPS**)—IDL-based VIIRS ocean color data visualization and processing package
  - Wang, X., X. Liu, L. Jiang, M. Wang, and J. Sun, "VIIRS ocean color data visualization and processing with IDL-based NOAA-SeaDAS", *Proc. SPIE 9261*, 8 Nov. 2014.
- **Work with users to meet their requirements.**

Two Data Streams for VIIRS Ocean Color EDR

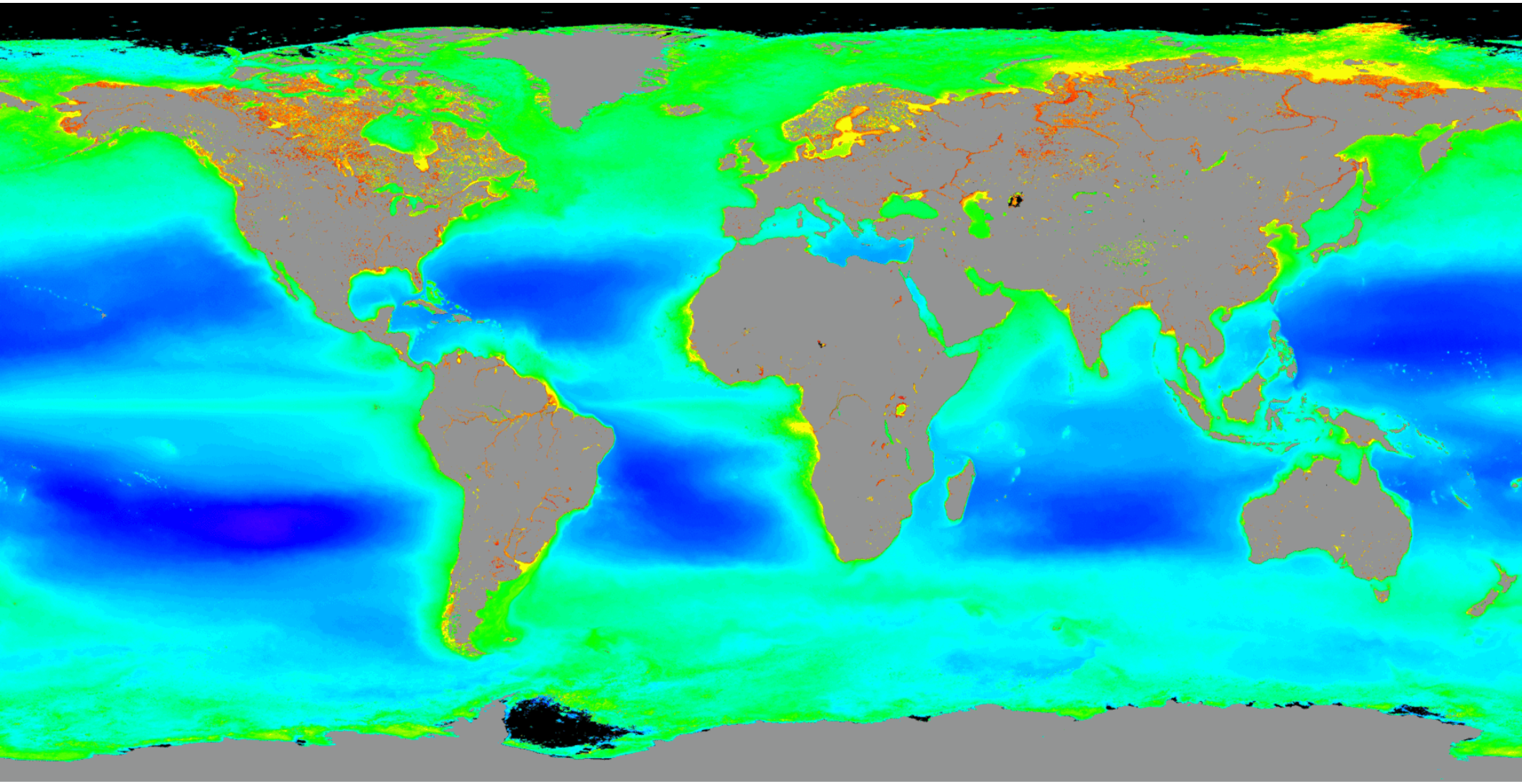
To meet requirements from **All** users (operational, research, modeling, etc.), we have been routinely producing VIIRS global ocean color products in **two data streams**: Near-Real-Time (NRT) and Delayed Science-Quality data.

Attribute	Near-Real Time (NRT)	Delayed Science-Quality
Latency:	Best effort, as soon as possible (~12-24h)	Best effort, on a 1-2-week delay
Processing System:	MSL12	MSL12
SDR:	IDPS Operational SDR	OC-Improved SDR
Ancillary Data:	Global Forecast System (GFS) Model	Science quality (assimilated; GDAS) from NCEP
Spatial Coverage:	May be gaps due to various issues	Complete global coverage
Processed by:	CoastWatch, transferring to OSPO (operational) FY16	NOAA/STAR
Distributed by:	CoastWatch, OSPO	CoastWatch, NCEI
Archive Plans:	Yes, from OSPO to NCEI	Yes, from CoastWatch to NCEI
Full Mission Reprocessing:	No	Yes, every ~2-3 years or as needed

VIIRS Mission-long Ocean Color Data Reprocessing

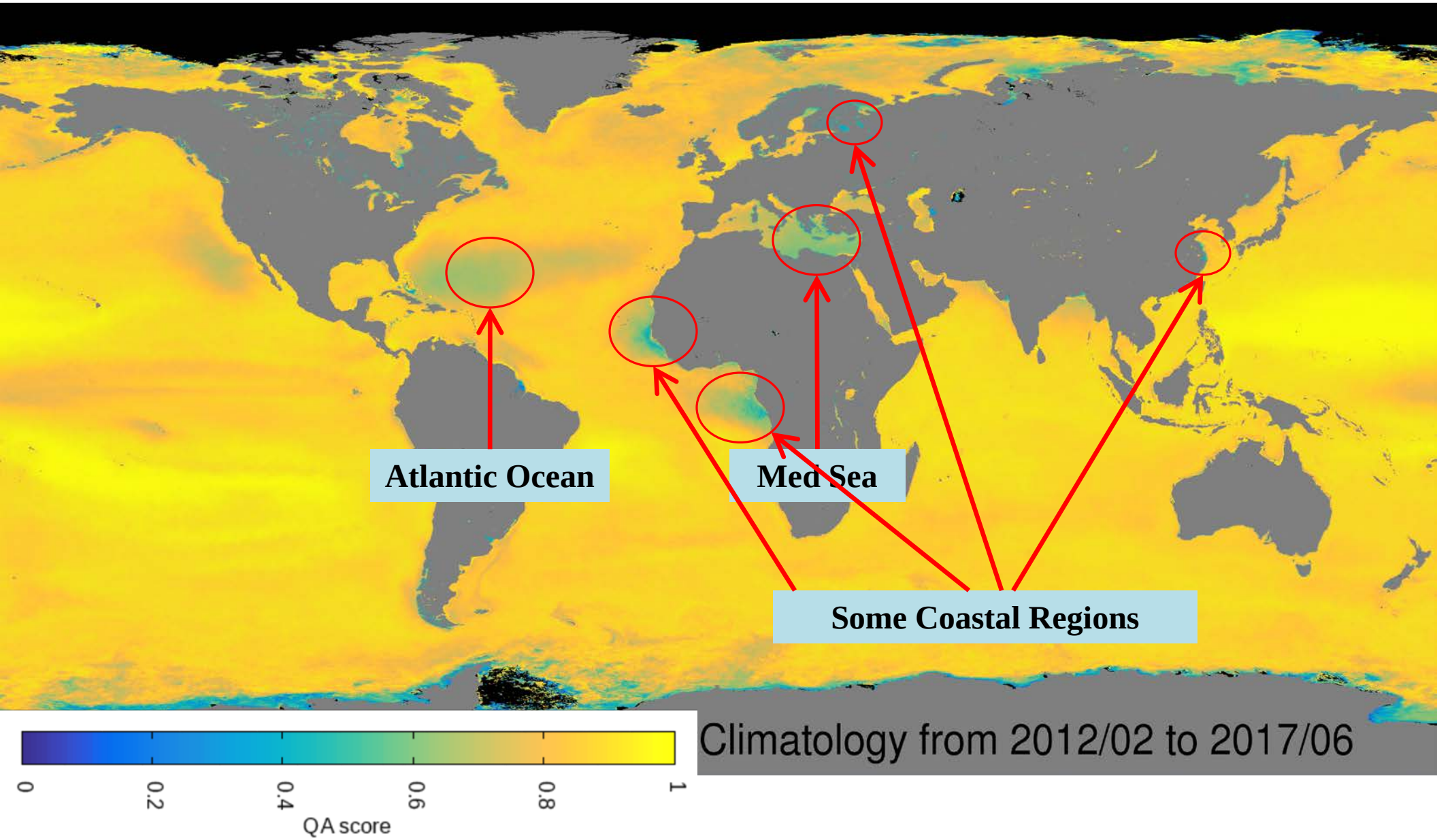
- ✓ We have recently reprocessed VIIRS mission-long ocean color data products for the Science Quality data stream in **April 2017**. This is the **second data reprocessing** due to some significant improvements (algorithms and SDR). The first VIIRS mission-long OC data reprocessing was completed in May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

VIIRS Climatology Ocean Color Product Image (2012–2016)



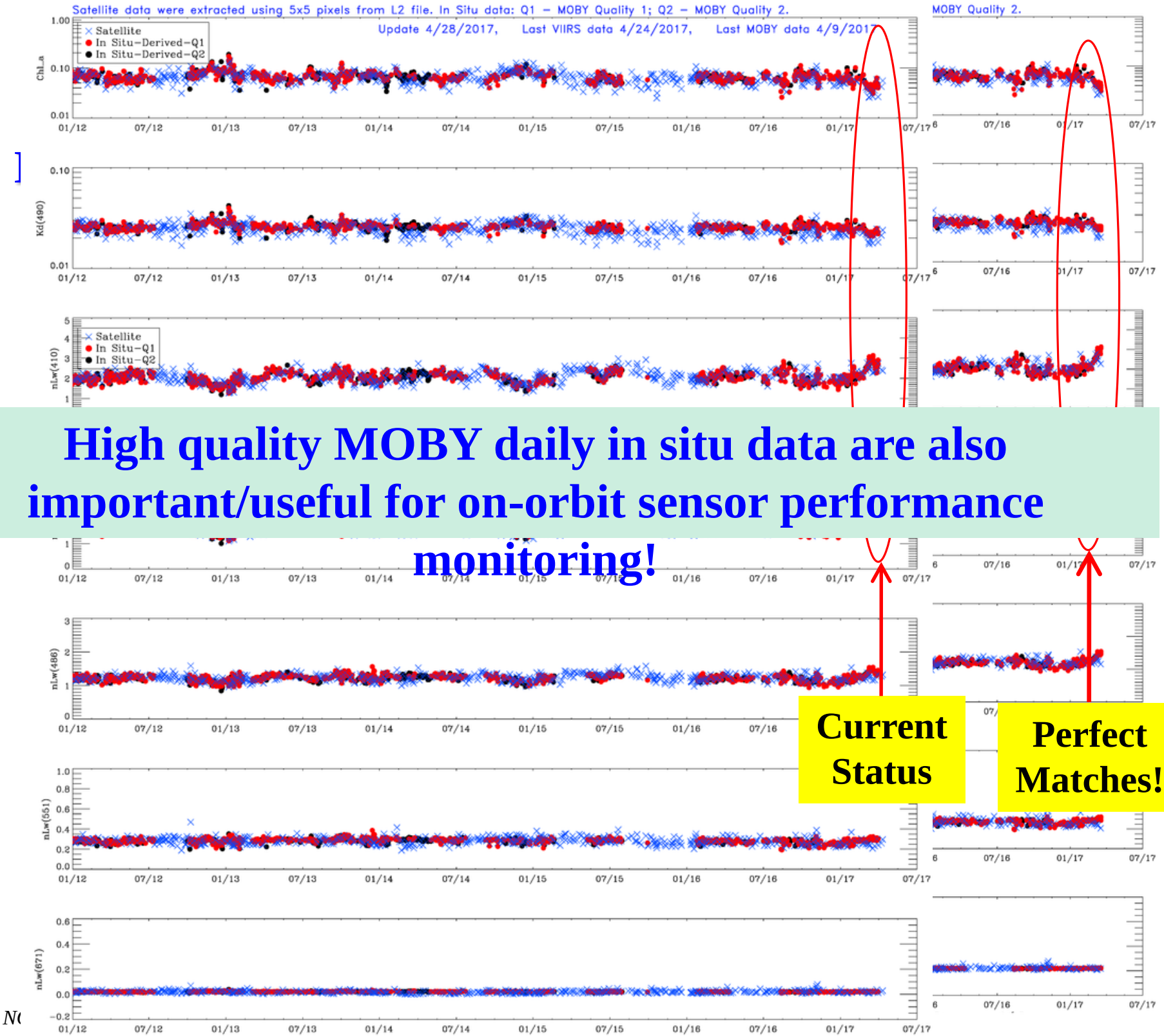
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VIIRS Climatology QA Score Image (2012–2017)



Wei, J., Z. Lee, and S. Shang (2016), "A system to measure the data quality of spectral remote-sensing reflectance of aquatic environments", *J. Geophys. Res., Oceans*, 121, 8189-8207, doi:10.1002/2016JC012126.

Menghua Wang, NOAA/NESDIS/STAR



Menghua Wang, N(

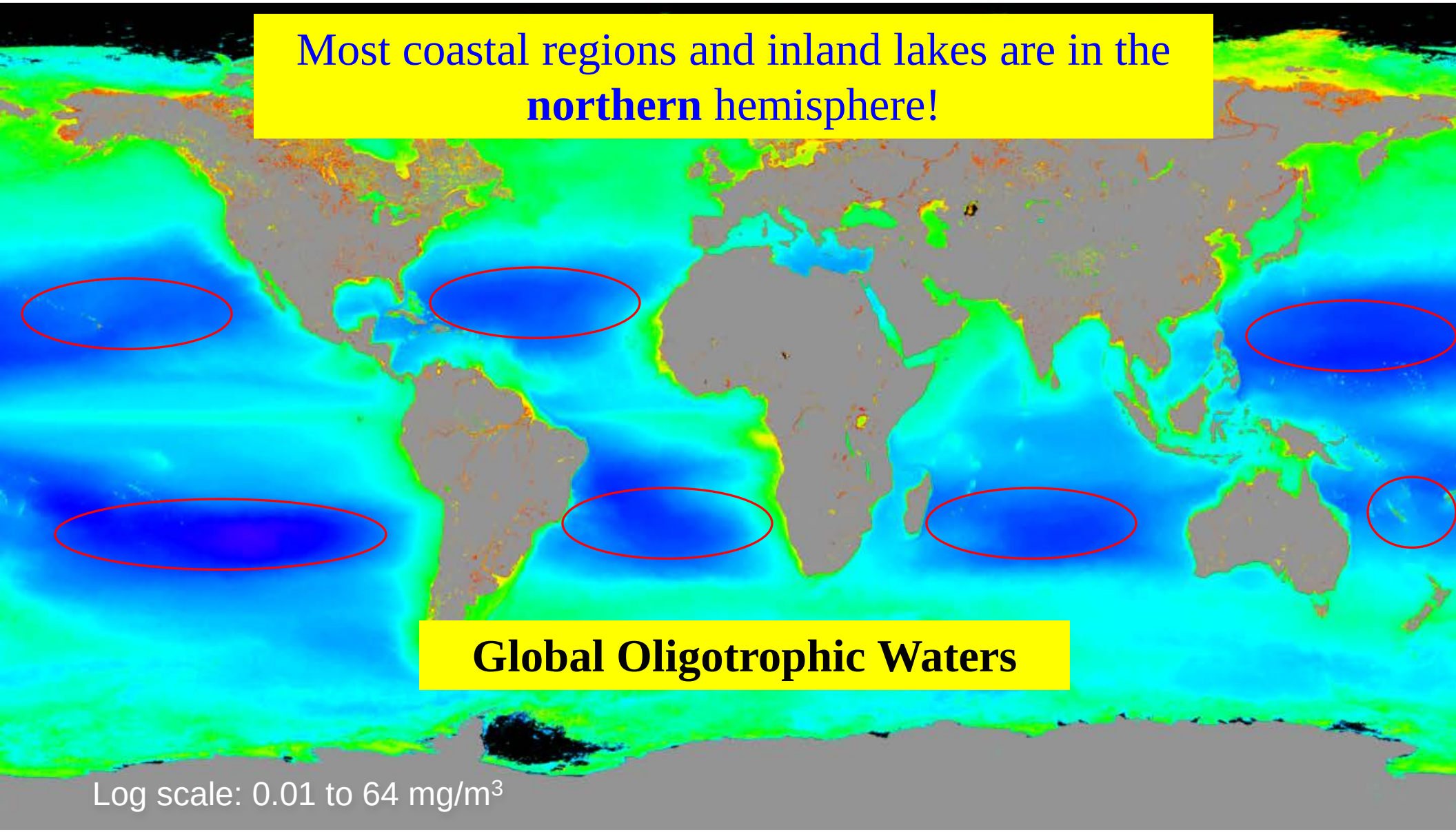
MOBY

Statistics of VIIRS versus In-Situ (MOBY)

VIIRS	OC-SDR NIR (Gain in 2017-03-26)				OC-SDR NIR (Gain in 2017-03-26)			
Product	**RATIO (SAT/ENV)**				**DIFFERENCE (SAT-ENV)**			
	AVG	**MED**	**STD**	**No**	**AVG**	**MED**	**STD**	**%Diff**
$nL_w(410)$	**1.0179**	1.0153	0.096	557	**0.0264**	0.0329	0.1899	**1.29**
$nL_w(443)$	**1.0159**	1.0119	0.092	557	**0.0196**	0.0181	0.1499	**1.18**
$nL_w(486)$	**1.0164**	1.0124	0.088	557	**0.0151**	0.0153	0.1048	**1.24**
$nL_w(551)$	**1.0276**	1.0098	0.135	557	**0.0062**	0.0029	0.0374	**2.17**
$nL_w(671)$	**1.1219**	1.0045	0.498	527	**0.0021**	0.0001	0.0099	**10.04**
$nL_w(638)$	**1.0656**	0.9366	0.545	555	**0.0010**	-0.0018	0.0155	**3.28**

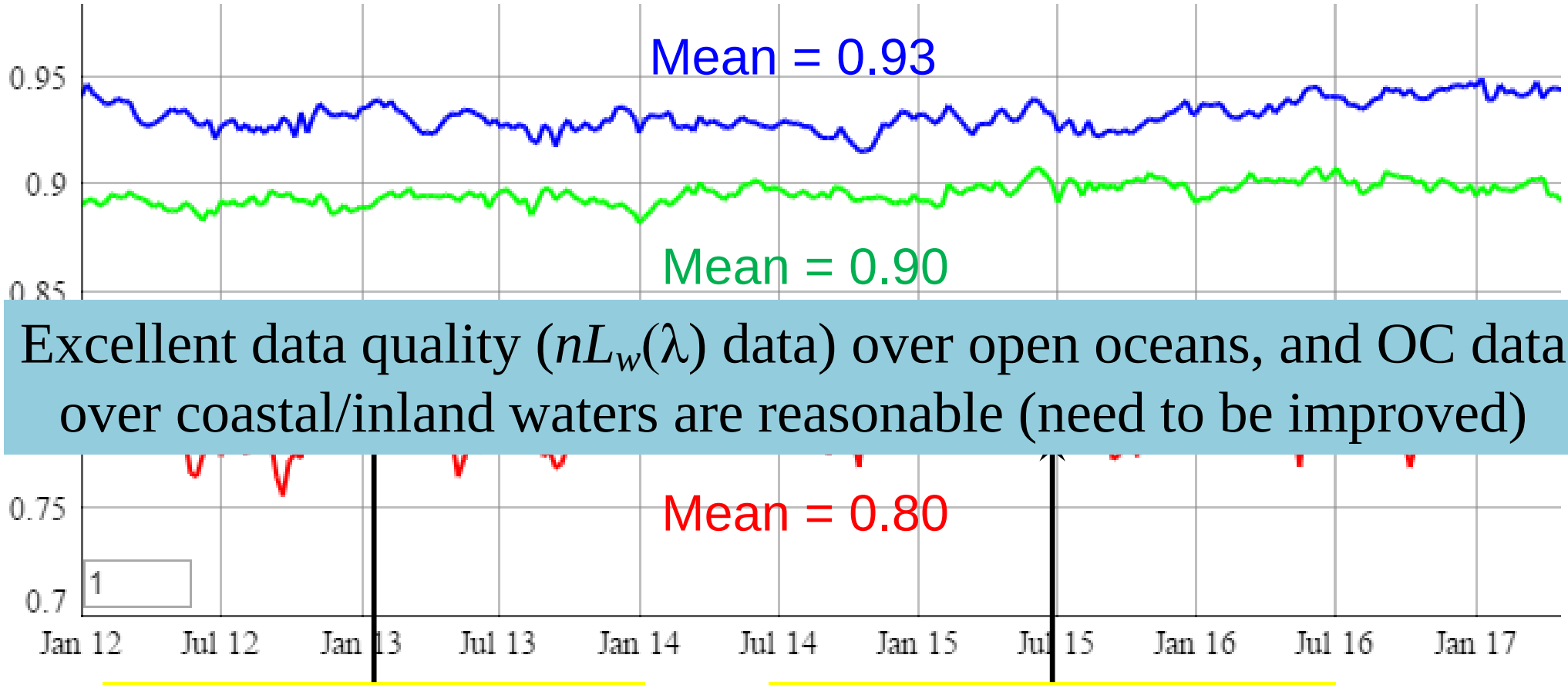
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VIIRS Climatology Chlorophyll-a Image (2012–2016)



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



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

Higher score in winter

Lower score in summer

Blue: Global Oligotrophic Waters

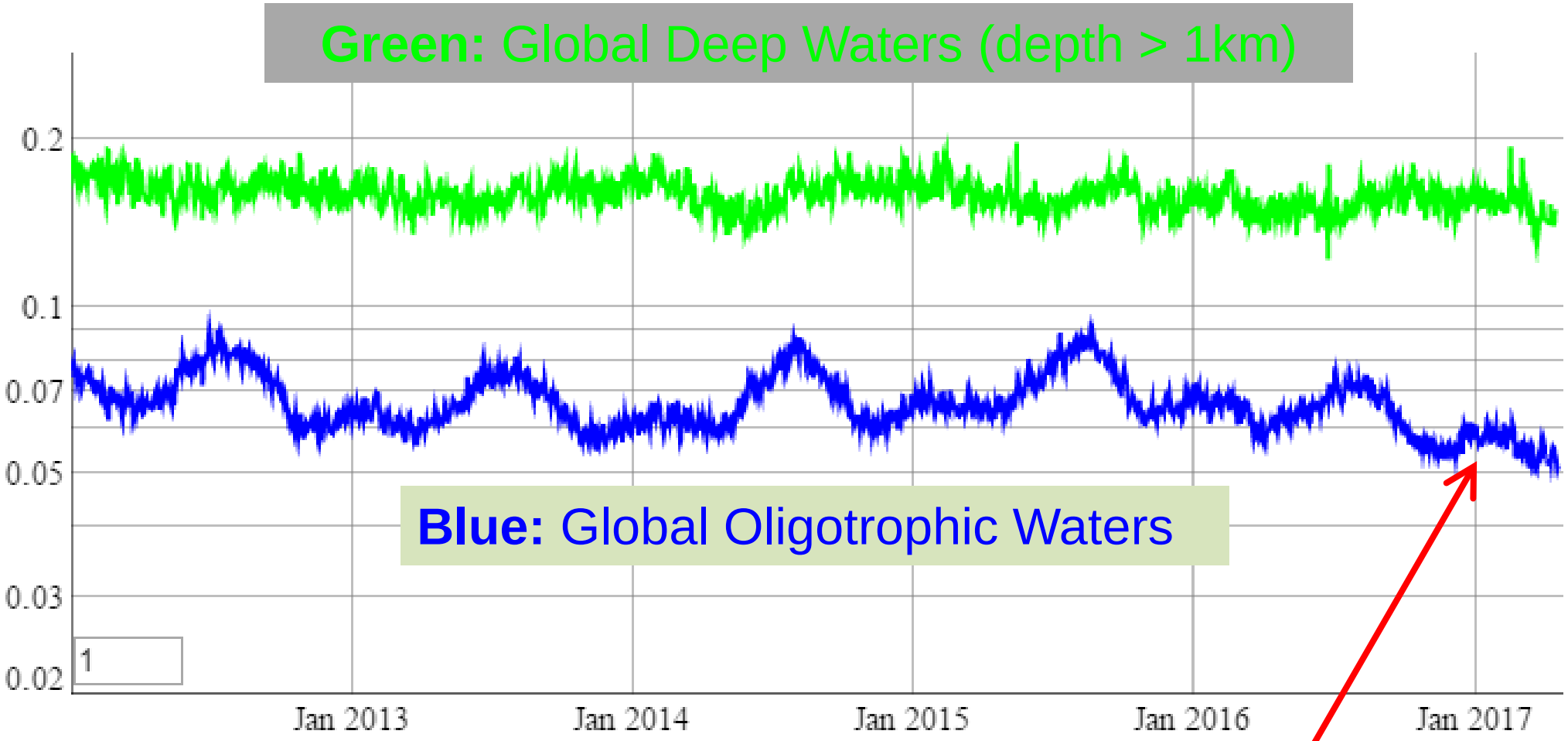
Green: Global Deep Waters (depth > 1km)

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

VIIRS science quality OC data are processed using the MSL12!

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VIIRS-derived Daily Chl-a

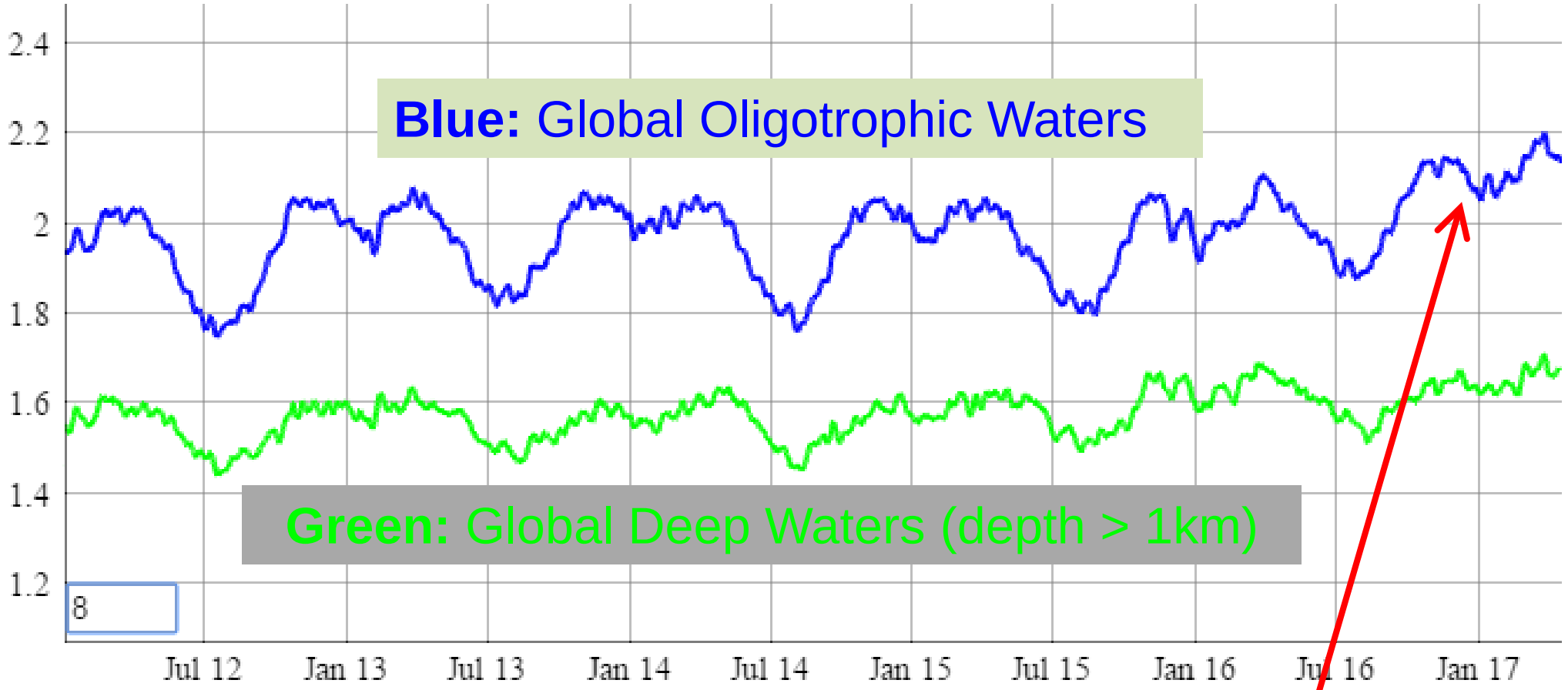


Slightly Chl-a drop over oligotrophic waters

VIIRS science quality OC data are processed using the MSL12!

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

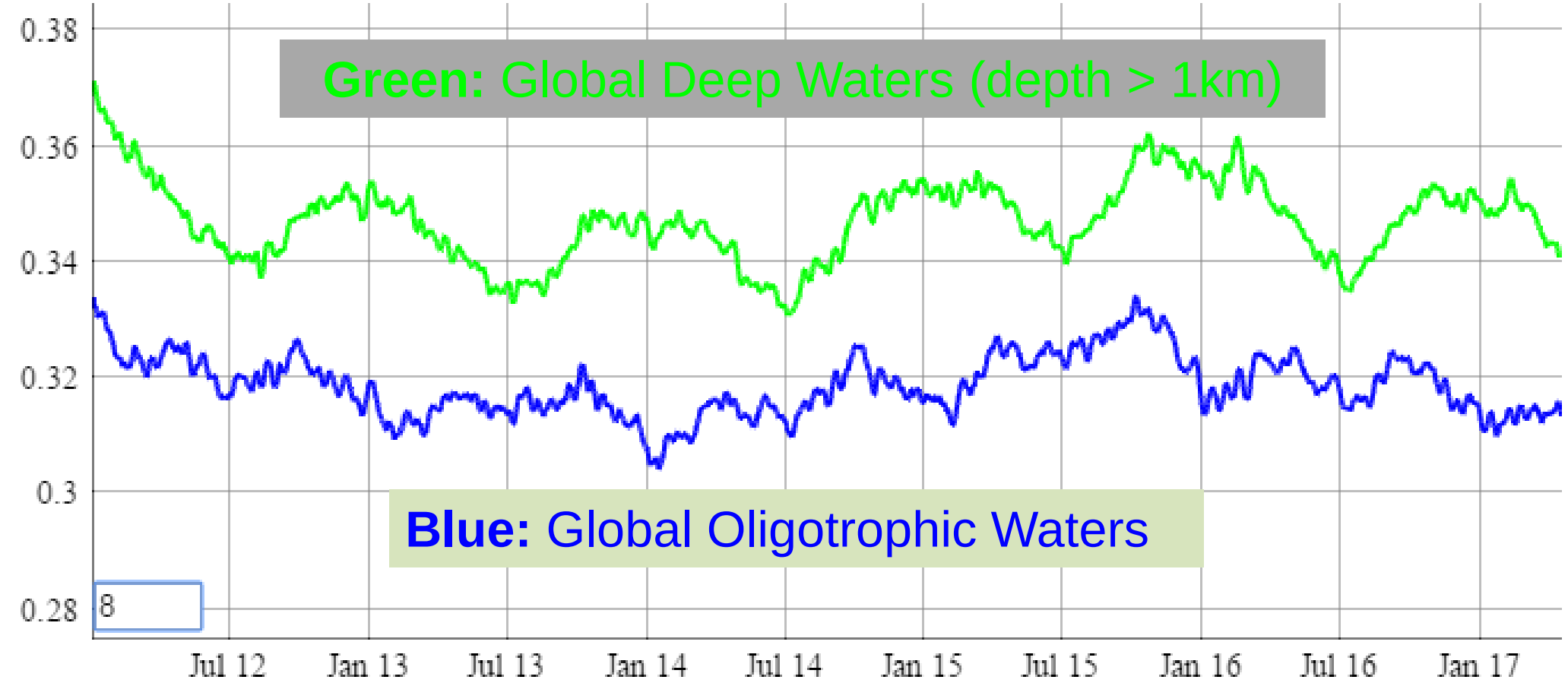


Water getting **Bluer** recently?

VIIRS science quality OC data are processed using the MSL12!

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VIIRS-derived 8-day $nL_w(551)$

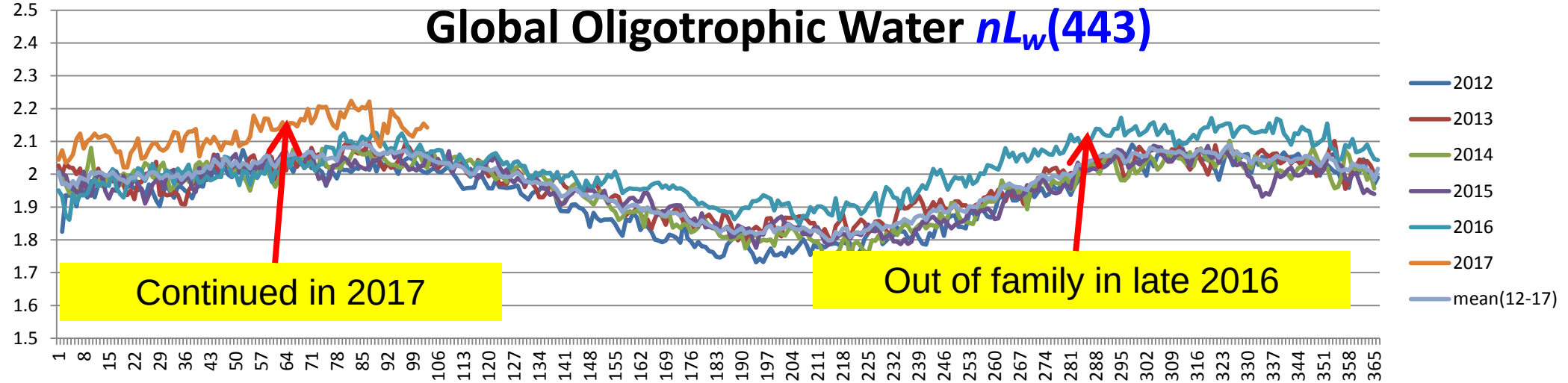


Quite stable in VIIRS-derived $nL_w(551)$!

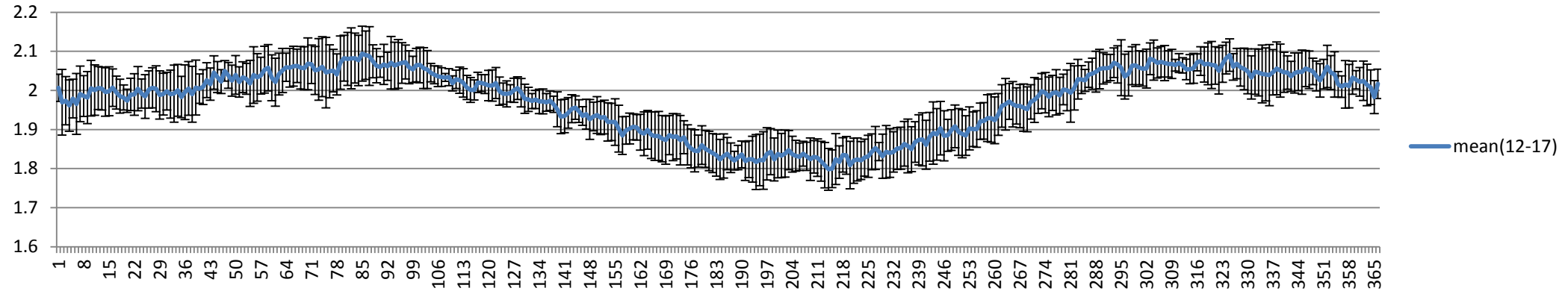
VIIRS science quality OC data are processed using the MSL12!

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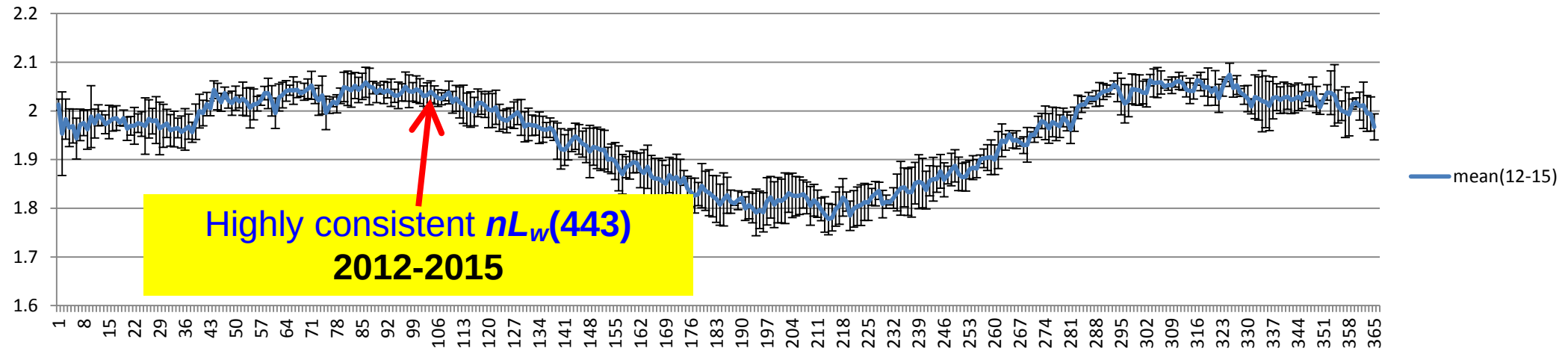
Global Oligotrophic Water $nL_w(443)$



Mean & STD (2012-2017)



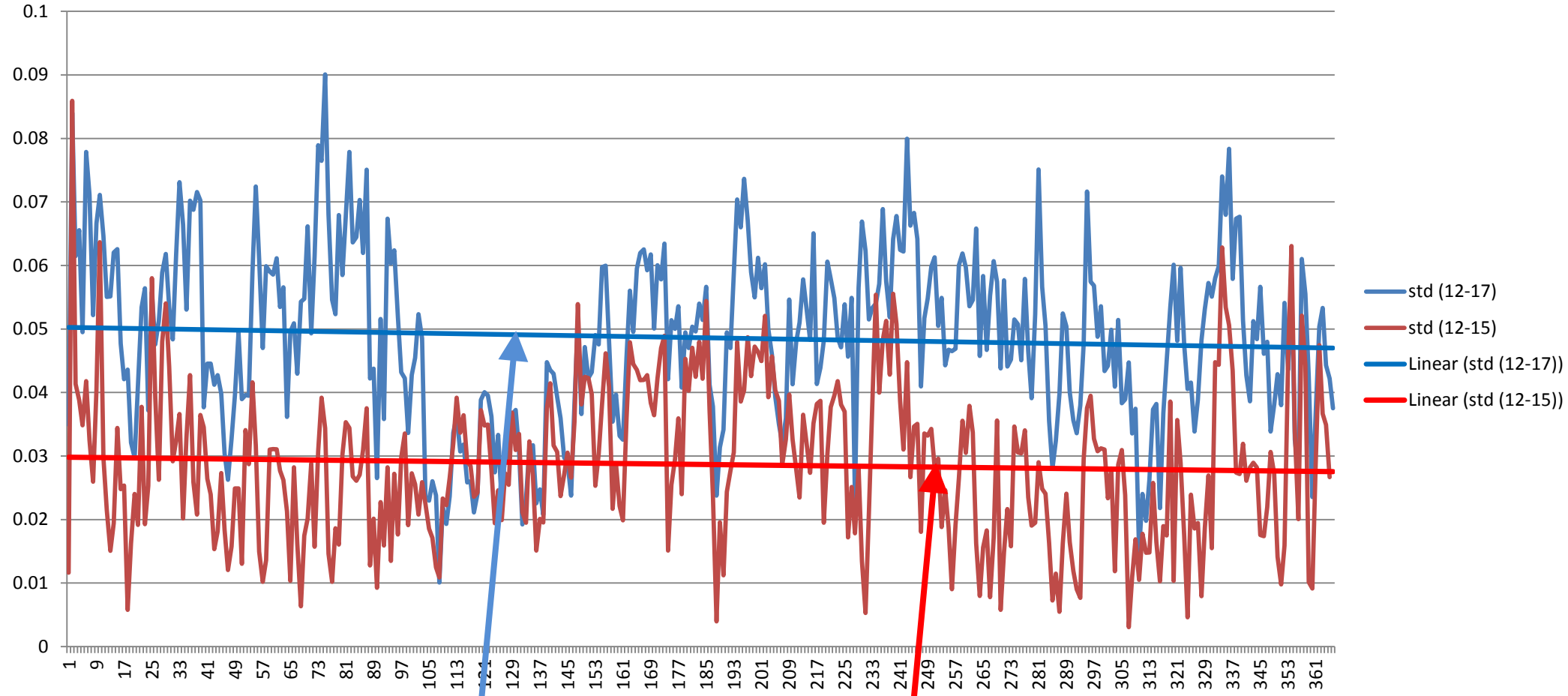
Mean & STD (2012-2015)



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Global Oligotrophic Water

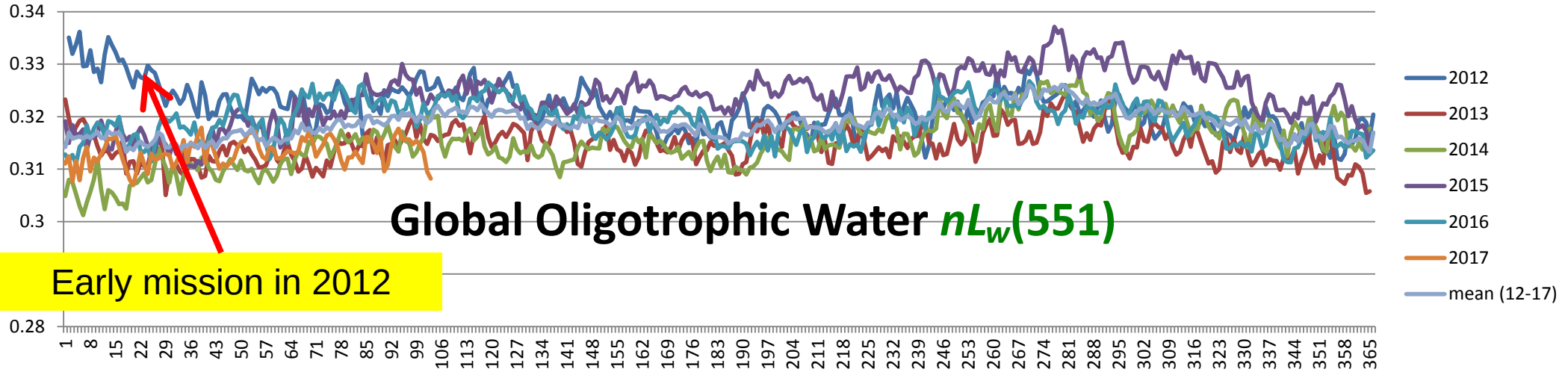
$nL_w(443)$ STD Values



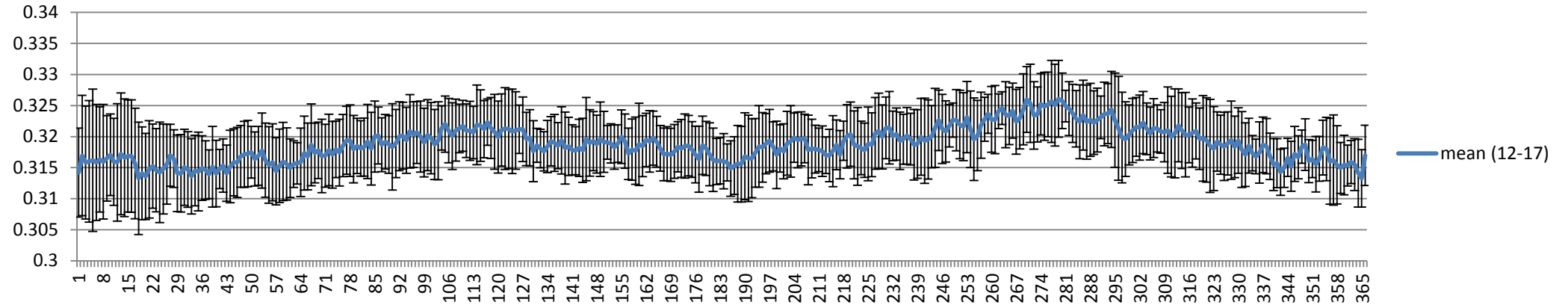
STD ~**0.05** for **2012-2017**

STD ~**0.03** for **2012-2015**

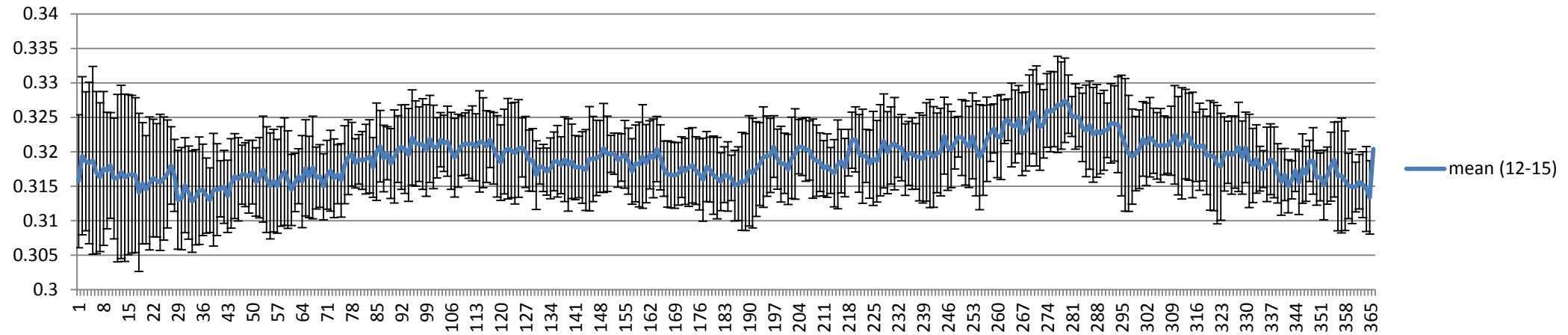
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Mean & STD (2012-2017)



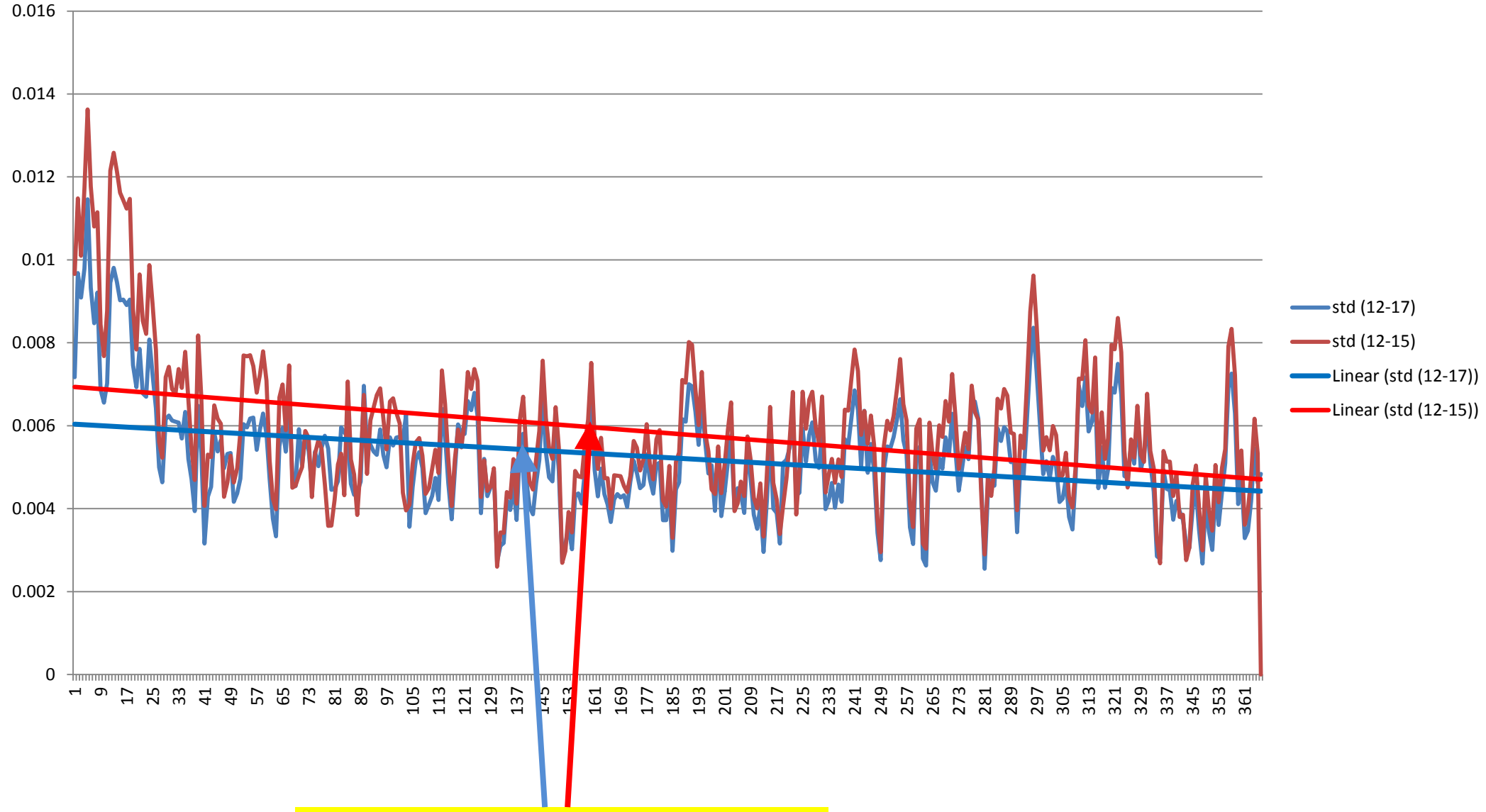
Mean & STD (2012-2015)



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Global Oligotrophic Water

nL_w(551) STD Values



Similar STD ~**0.005-0.007**

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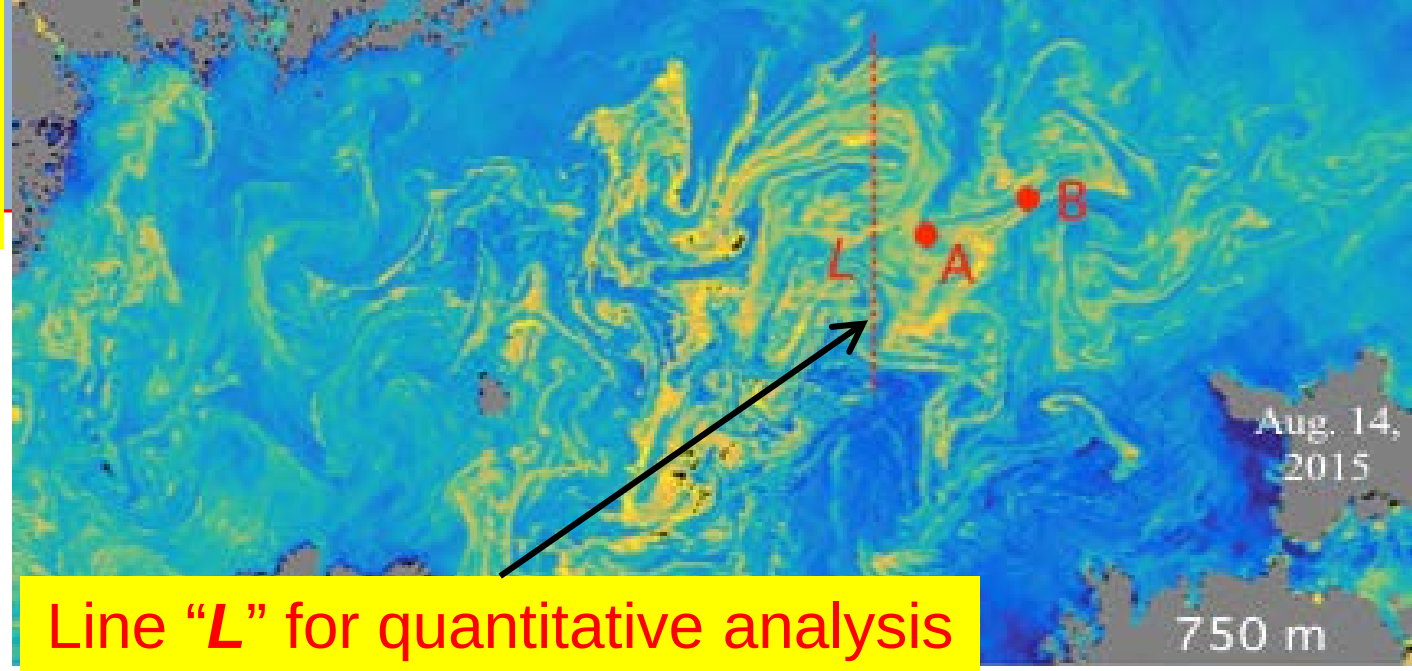
New VIIRS $nL_w(638)$ with Imaging Bands

(Resolution at 375 m)

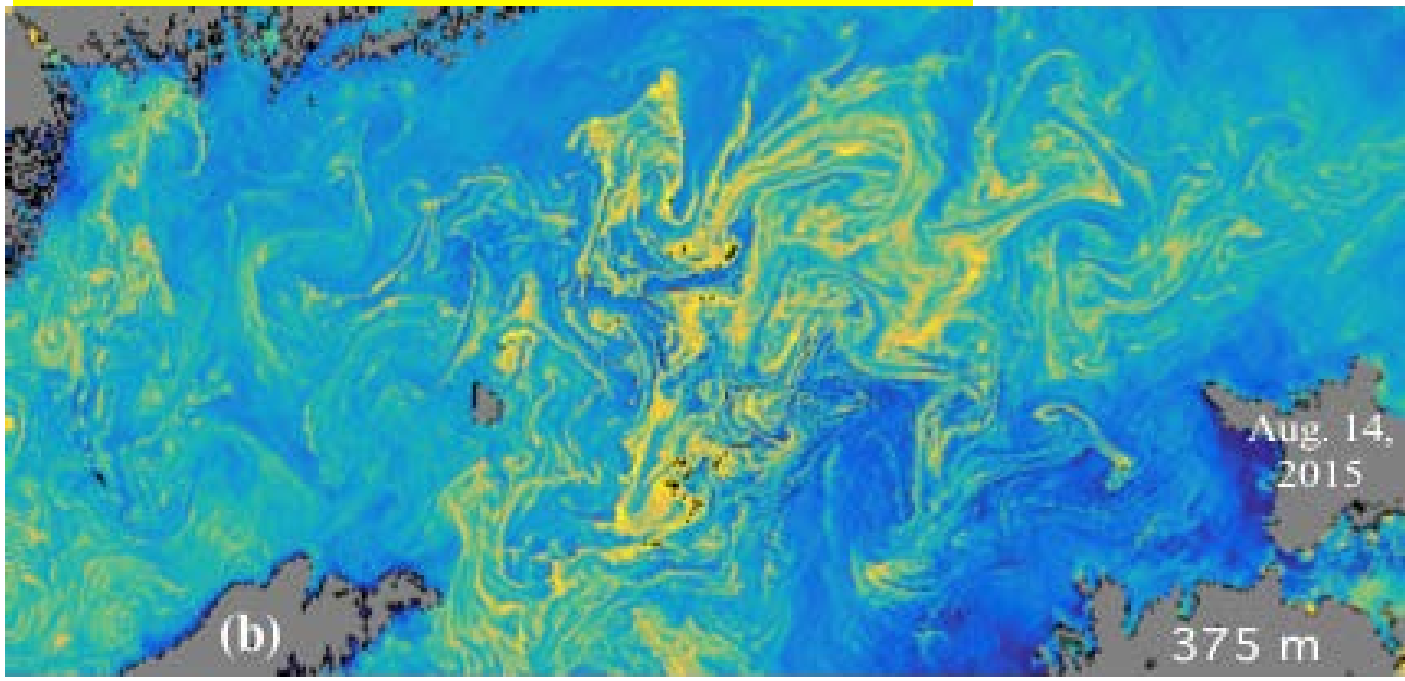
Example:

Algae Bloom in the Baltic Sea on August 14, 2015

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



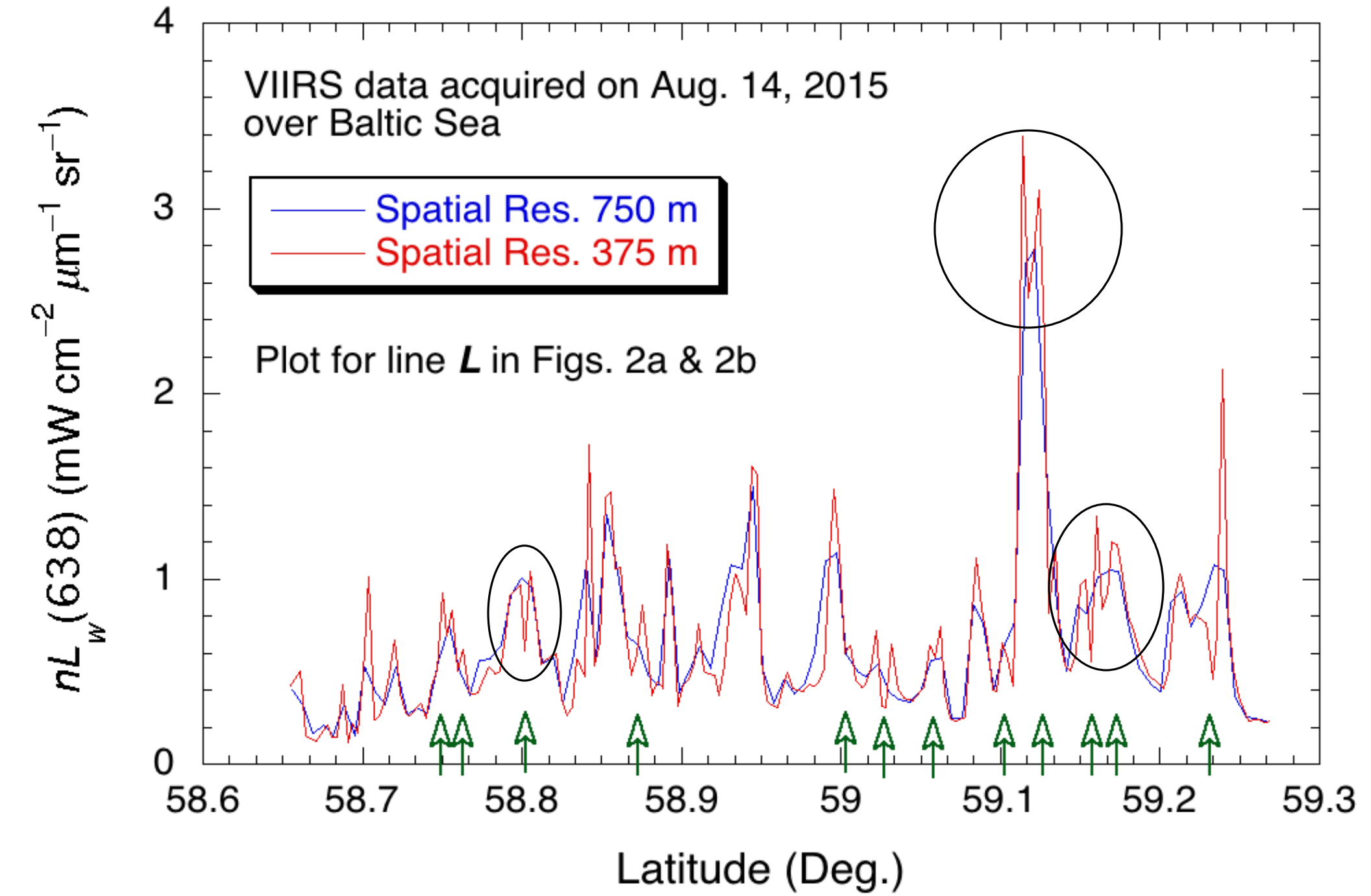
Line "*L*" for quantitative analysis



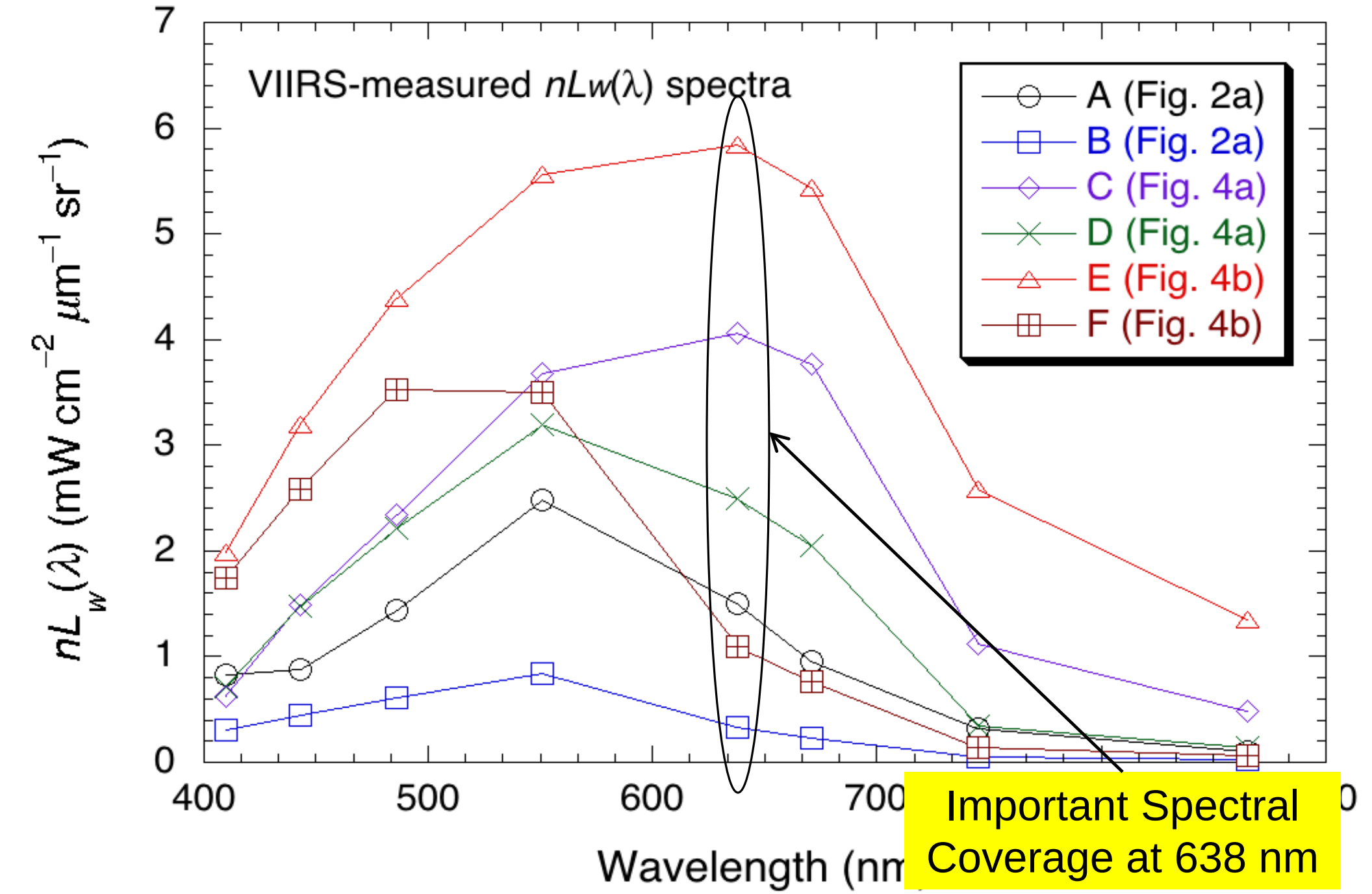


Wang, M. and L. Jiang (2017), "VIIRS-derived ocean color product using the imaging bands", *Remote Sen. Environ.* (Submitted).

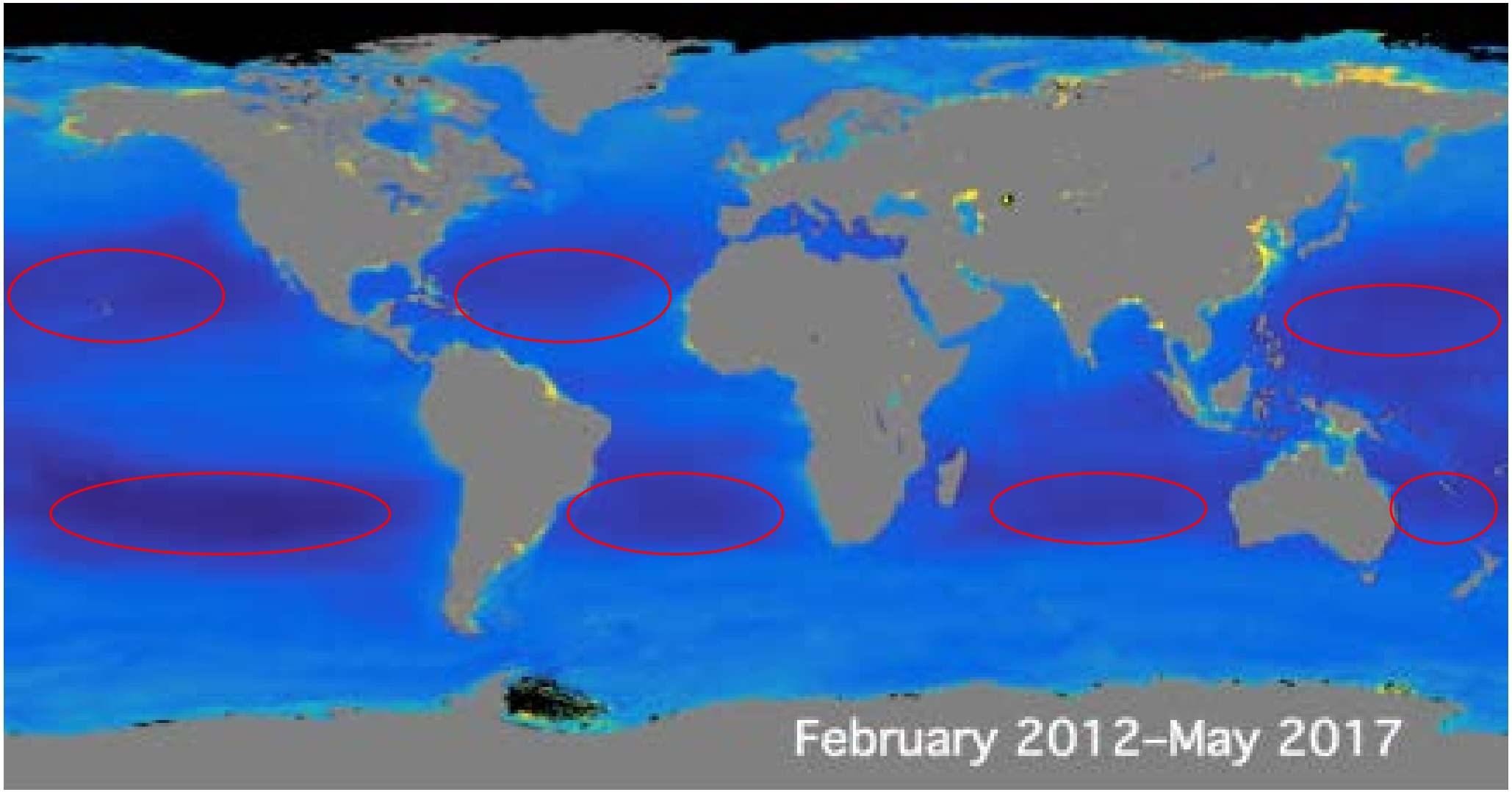
More Detailed Algae Bloom Information Provided by VIIRS High Spatial Resolution (375 m) $nL_w(638)$ Data



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



VIIRS-derived $nL_w(638)$ Climatology Image



$nL_w(638)$ (mW cm^{-2} μm^{-1} sr^{-1})

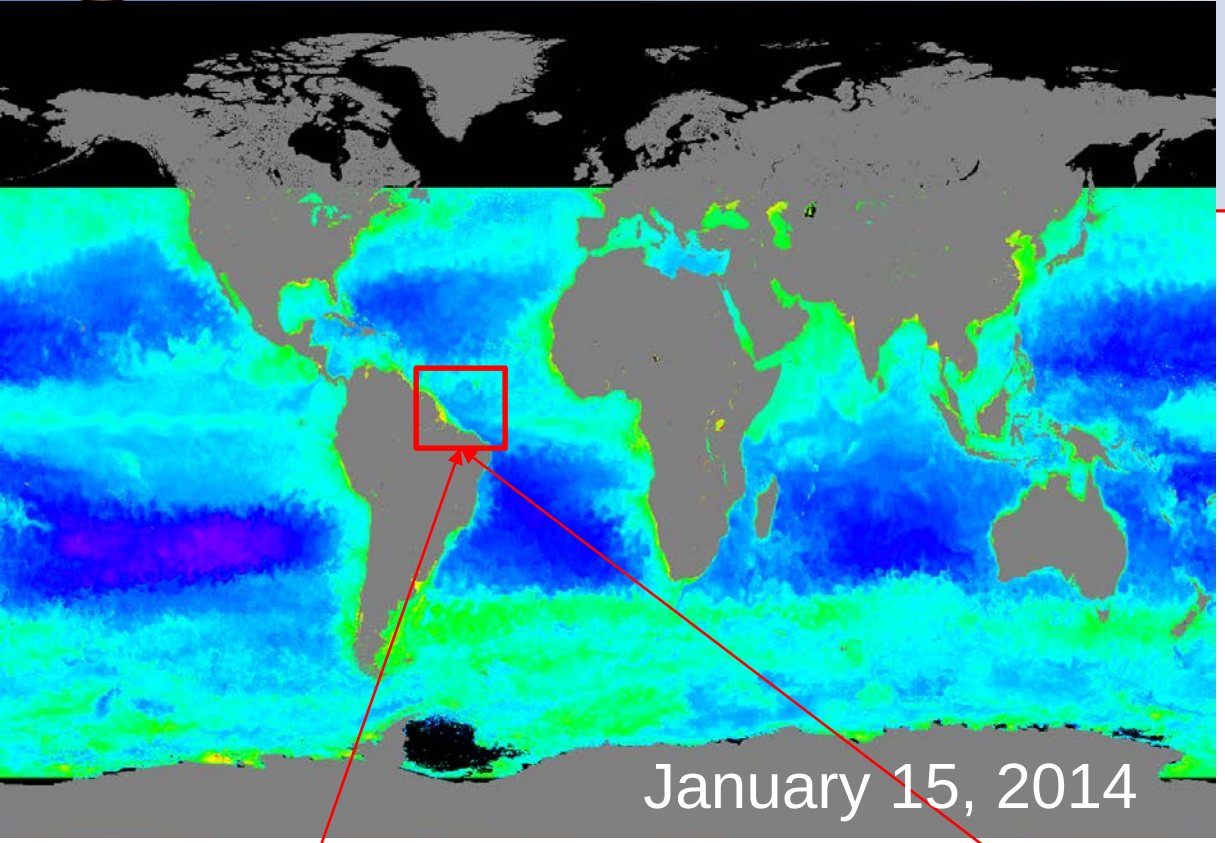
Land

0.03 0.1 0.3 1.0 3.0

No Data

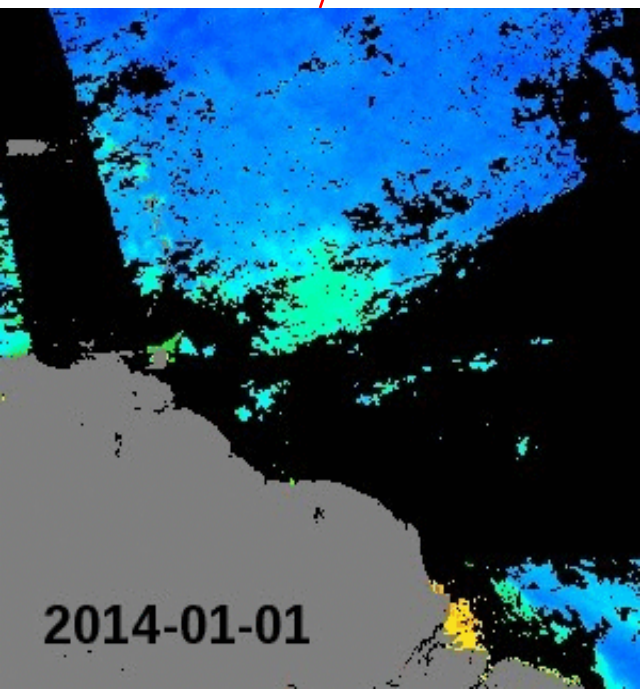
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Gap Filling Using the DINEOF Method

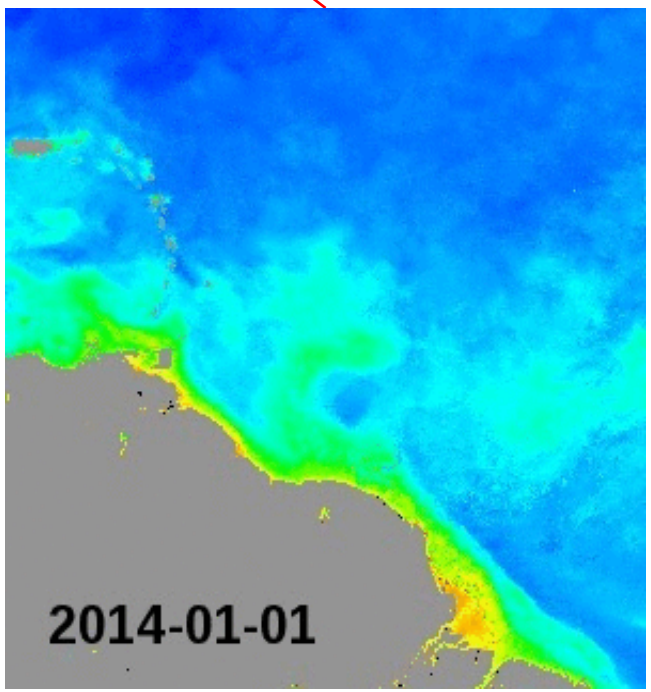


Examples of Reconstructed Chl-a Images (1)

Eddies near Amazon River
January 1-31, 2014



Original



Reconstructed

We can now see **eddy movement** in the reconstructed Chl-a images

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

NOAA Technical Report NESDIS 146

DOI: 10.7289/V52B8W0Z

Report for
Dedicated JPSS VIIRS Ocean Color
Calibration/Validation Cruise



Washington, D.C.
September 2015

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

Dedicated VIIRS Cal/Val Cruises

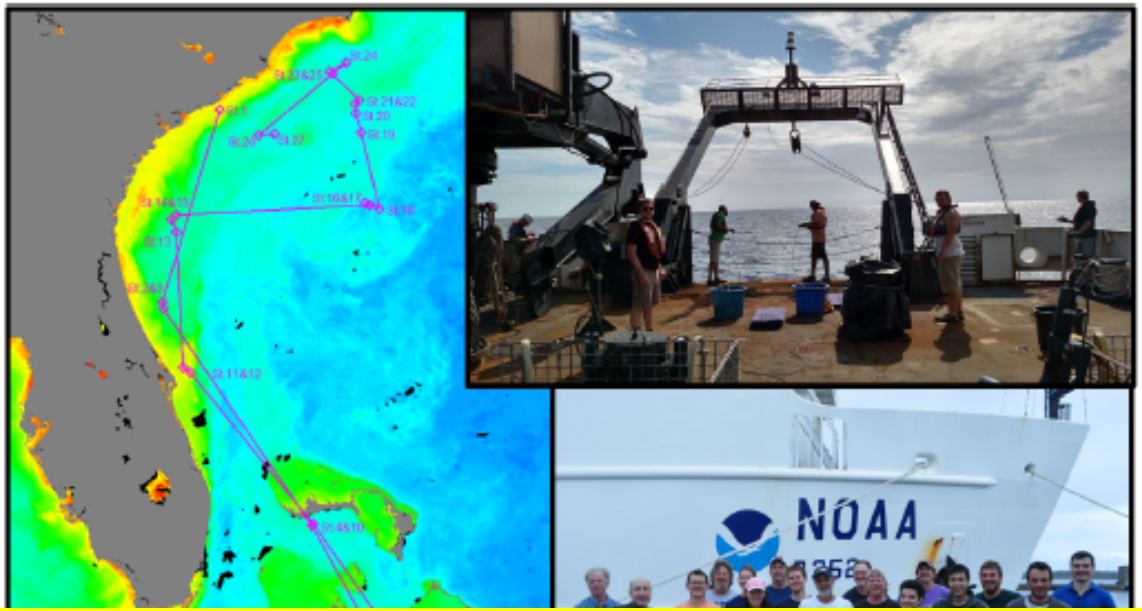
Ondrusek, M., E. Stengel, V. P. Lance, M. Wang, K. J. Voss, G. Zibordi, M. Talone, Z. P. Lee, J. Wei, J. Lin, C. Hu, D. English, C. Kovach, J. Cannizzaro, A. Gilerson, S. Ahmed, A. Ibrahim, A. El-Habashi, R. Foster, R. Arnone, R. Vandermeulen, S. Ladner, W. Goode, J. I. Goes, H. Gomes, A. Chekalyuk, K. McKee, S. Freeman, A. Neeley, and B. C. Johnson, "Report for Dedicated JPSS VIIRS Ocean Color Calibration/Validation Cruise," *NOAA Technical Report NESDIS 146*, V. P. Lance (ed.), NOAA National Environmental Satellite, Data, and Information Service, Silver Spring, Maryland, 2015. http://dx.doi.org/10.7289/V52B8W0Z

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

NOAA Technical Report NESDIS 148

doi:10.7289/V5/TR-NESDIS-148

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





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

Ondrusek, M., V. P. Lance, E. Stengel, M. Wang, R. Arnone, S. Ladner, W. Goode, R. Vandermeulen, S. Freeman, J. E. Chaves, A. Mannino, A. Gilerson, S. Ahmed, C. Carrizo, A. El-Habashi, R. Foster, M. Ottaviani, J. I. Goes, H. Gomes, K. McKee, C. Hu, C. Kovach, D. English, J. Cannizzaro, B. C. Johnson, Z. P. Lee, J. Wei, Q. Wang, J. Lin, N. Tufillaro, J. Nahorniak, C. O. Davis, and K. J. Voss, "Report for Dedicated JPSS VIIRS Ocean Color Calibration/Validation Cruise December 2015," *NOAA Technical Report NESDIS 148*, V. P. Lance (ed.), NOAA National Environmental Satellite, Data, and Information Service, Silver Spring, Maryland, 2016. http://dx.doi.org/10.7289/V5/TR-NESDIS-148

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

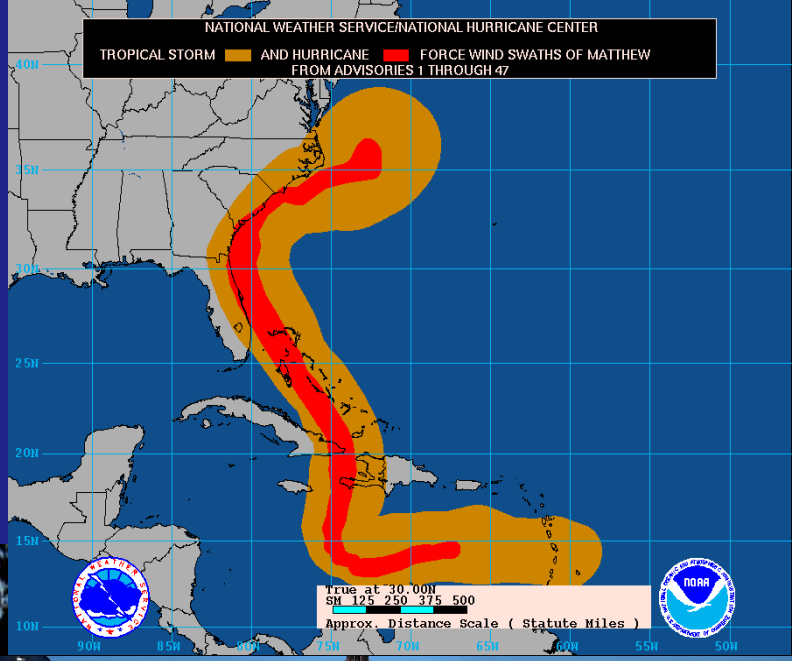
Dedicated VIIRS Cal/Val Cruise III

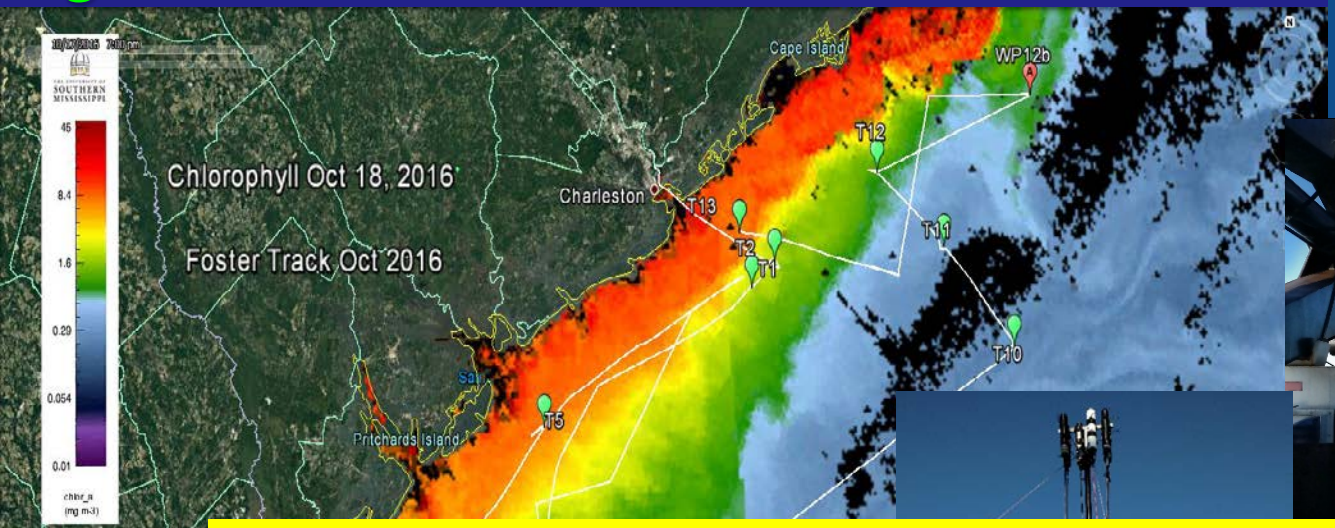
NOAA Ship *Nancy Foster*

5-18 October 2016

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

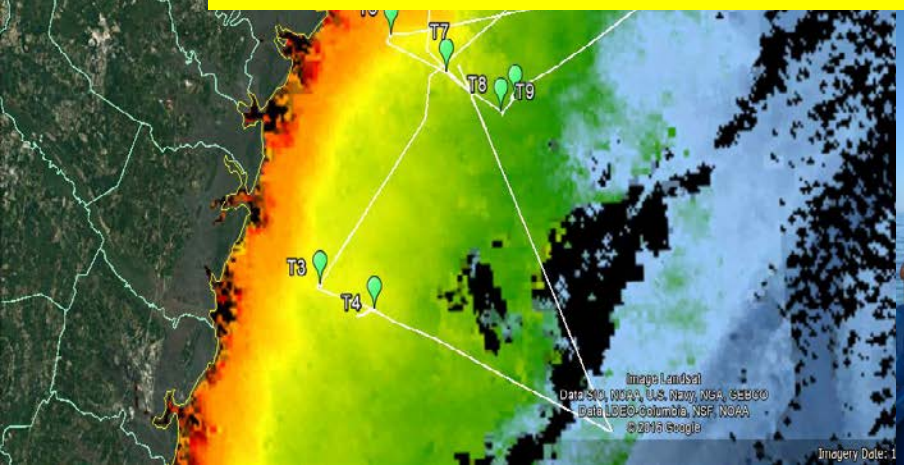
Measurements done just after Hurricane Matthew in the region **13-18 October 2016**.







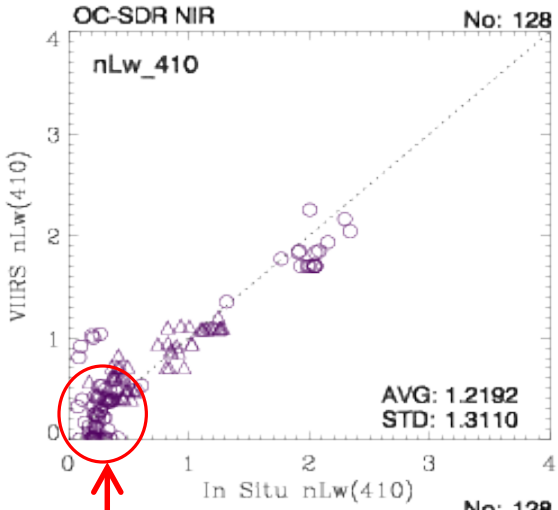
Report will be published soon (this year)!

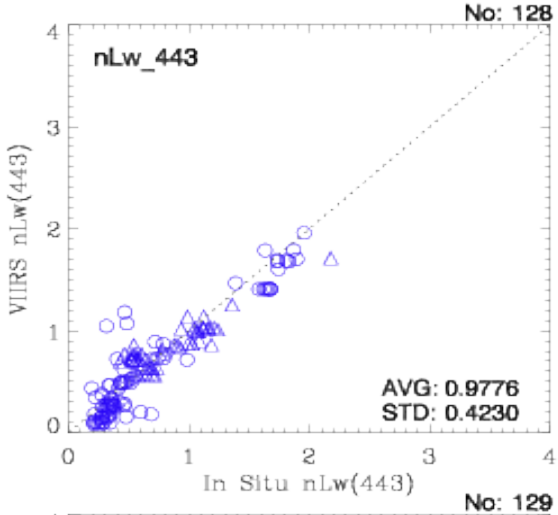




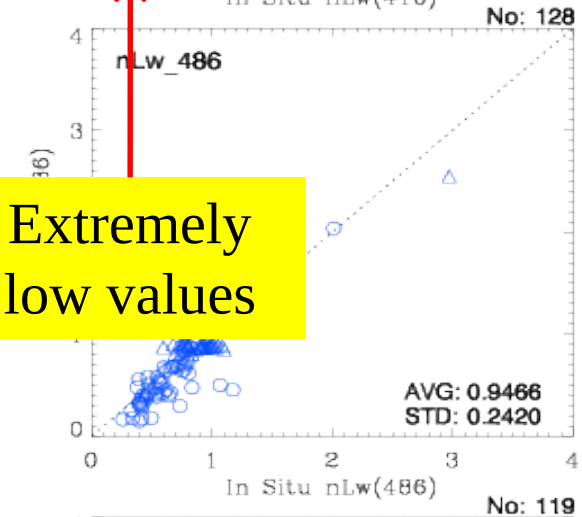


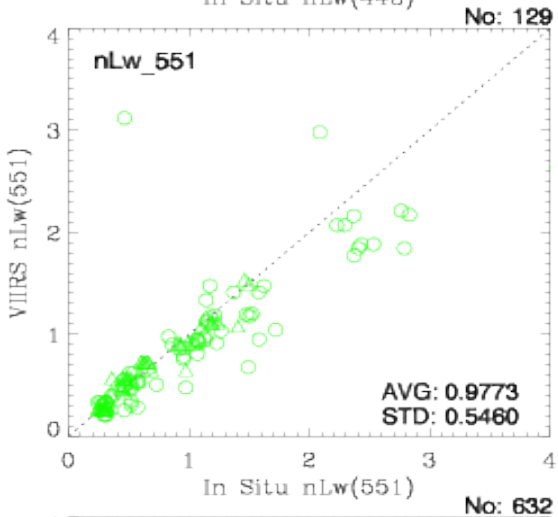
Validation Effort

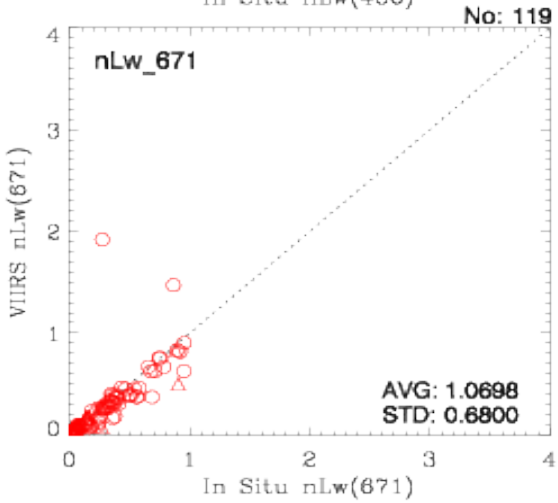


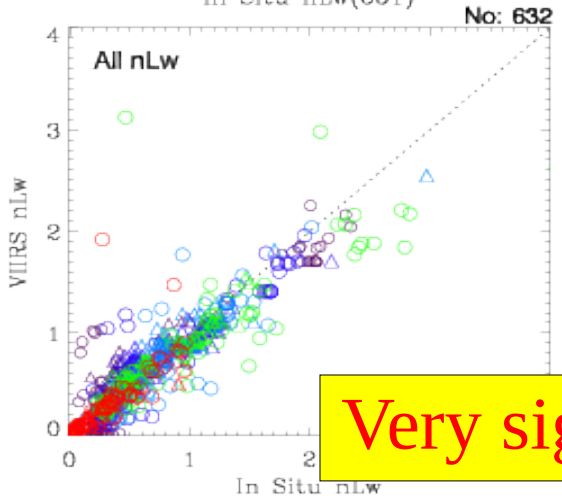


Extremely low values









VIIRS vs. In Situ Data

In Situ Data Sources:

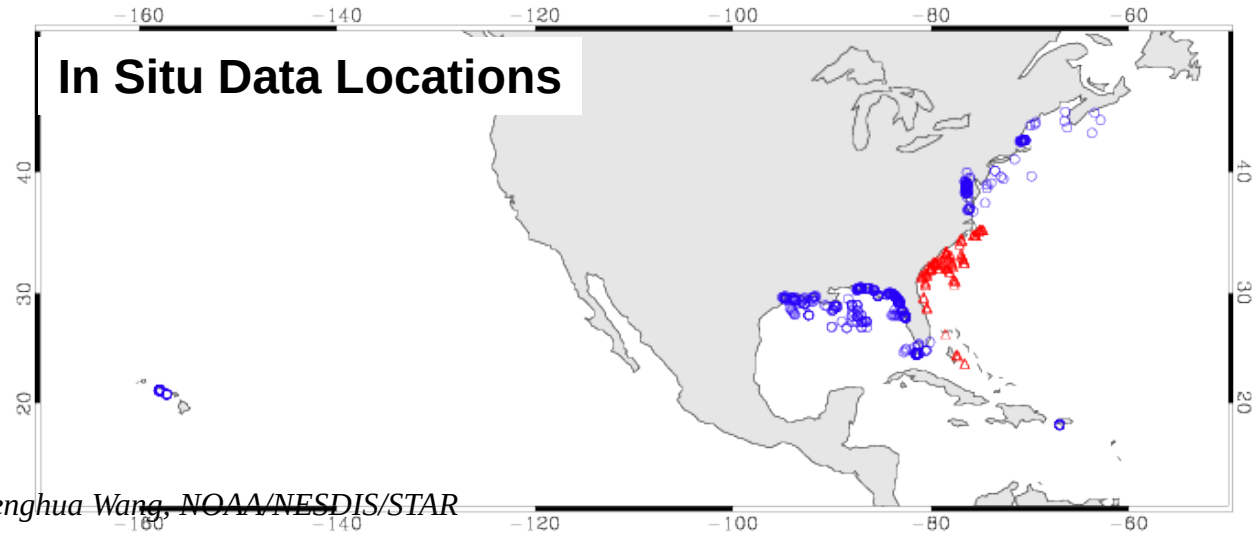
R. Arnone (U. South Miss.)
C. Davis (Oregon State U.)
C. Hu (U. South Florida)
Z. Lee (U. Mass. Boston)
M. Ondrusek (NOAA/STAR)
G. Zibordi (JRC)

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

Very significant amount of work!!

Statistics of VIIRS vs. In Situ Data

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



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

Menghua Wang, NOAA/NESDIS/STAR

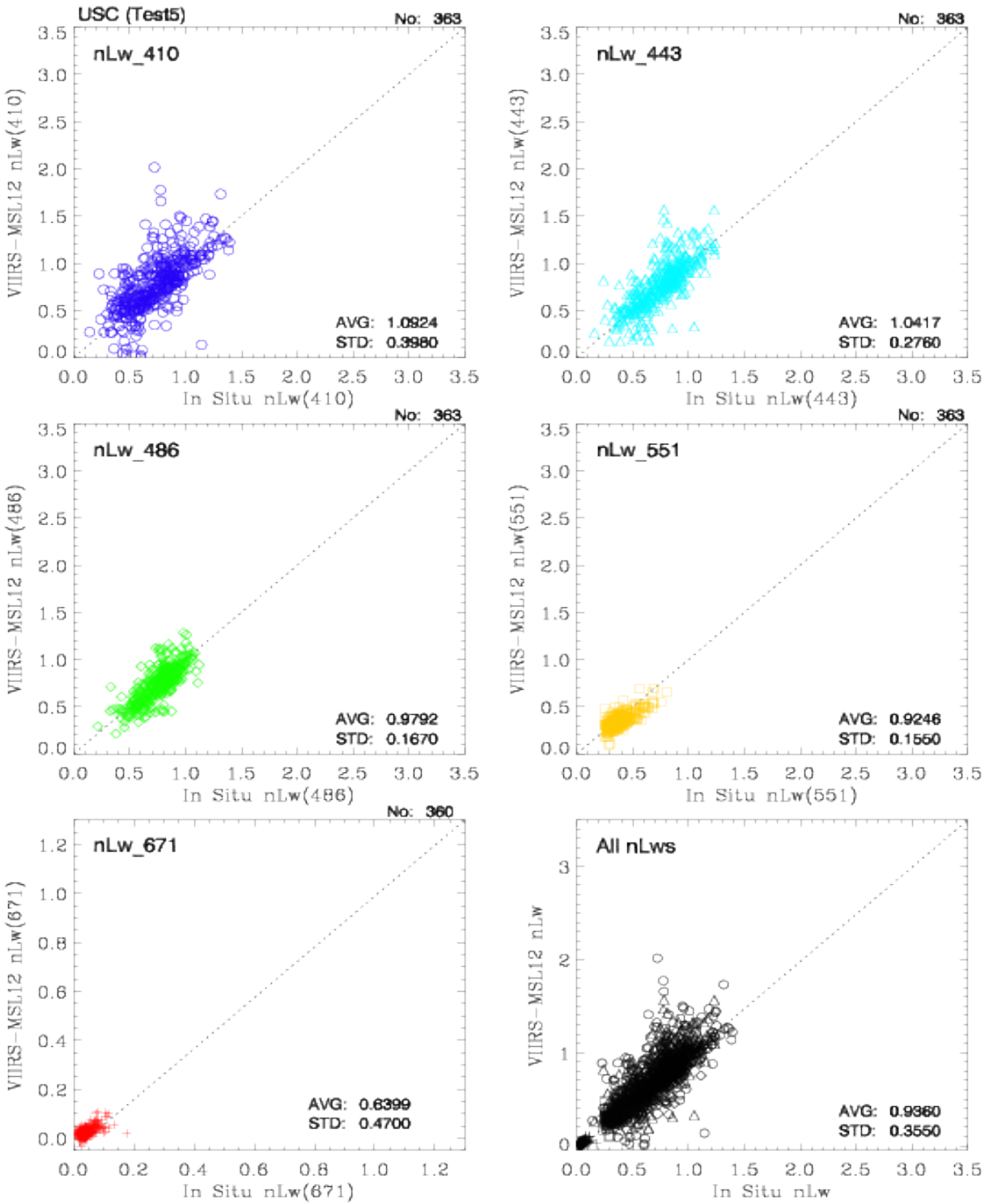
Matchup of

AERONET-OC In Situ

versus

VIIRS OC-SDR NIR

USC



Menghua Wang, NOAA/NESDIS/STAR

USC

Statistics of VIIRS OC (NIR) vs. In-Situ (AERONET-OC)

	OC-SDR The NIR Method							
	RATIO (SAT/ENV)				DIFFERENCE (SAT-ENV)			
	AVG	MED	STD	No	AVG	MED	STD	%Diff
$nL_w(410)$	**1.0924**	1.0213	0.398	363	**0.04474**	0.01420	0.2325	6.066
$nL_w(443)$	**1.0417**	0.9988	0.276	363	**0.02133**	-0.00100	0.1680	2.825
$nL_w(486)$	**0.9792**	0.9645	0.167	363	**-0.01838**	-0.02690	0.1145	-2.404
$nL_w(551)$	**0.9246**	0.9091	0.155	363	**-0.03356**	-0.03260	0.0598	-8.804
$nL_w(671)$	**0.6399**	0.5777	0.470	360	**-0.01737**	-0.01620	0.0185	-40.249
nL_w All	**0.9360**	0.9406	0.355	1812	**-0.00062**	-0.01760	0.1438	-0.115

Conclusions

- VIIRS global ocean color products have been routinely produced using the **NIR-**, **SWIR-**, and **NIR-SWIR-**based atmospheric correction algorithms, providing necessary satellite data for various applications in open oceans, coastal and inland waters, as well as for further improving data quality.
- Our evaluation results show that **VIIRS-SNPP is now capable of providing high quality global ocean color products in support of science research and operational applications**.
- We will prepare for the OC data processing for VIIRS-J1 in FY18, which will provide more complete global coverage with VIIRS-SNPP.

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

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

Thank You!

VIIRS SDR Calibration for Improvement of Ocean Color Products

Junqiang Sun[1,2] and Menghua Wang[1]

[1]NOAA/NESDIS Center for Satellite Applications and Research
E/RA3, 5830 University Research Ct., College Park, MD 20740, USA
[2]Global Science and Technology, 7855 Walker Drive, Maryland, USA

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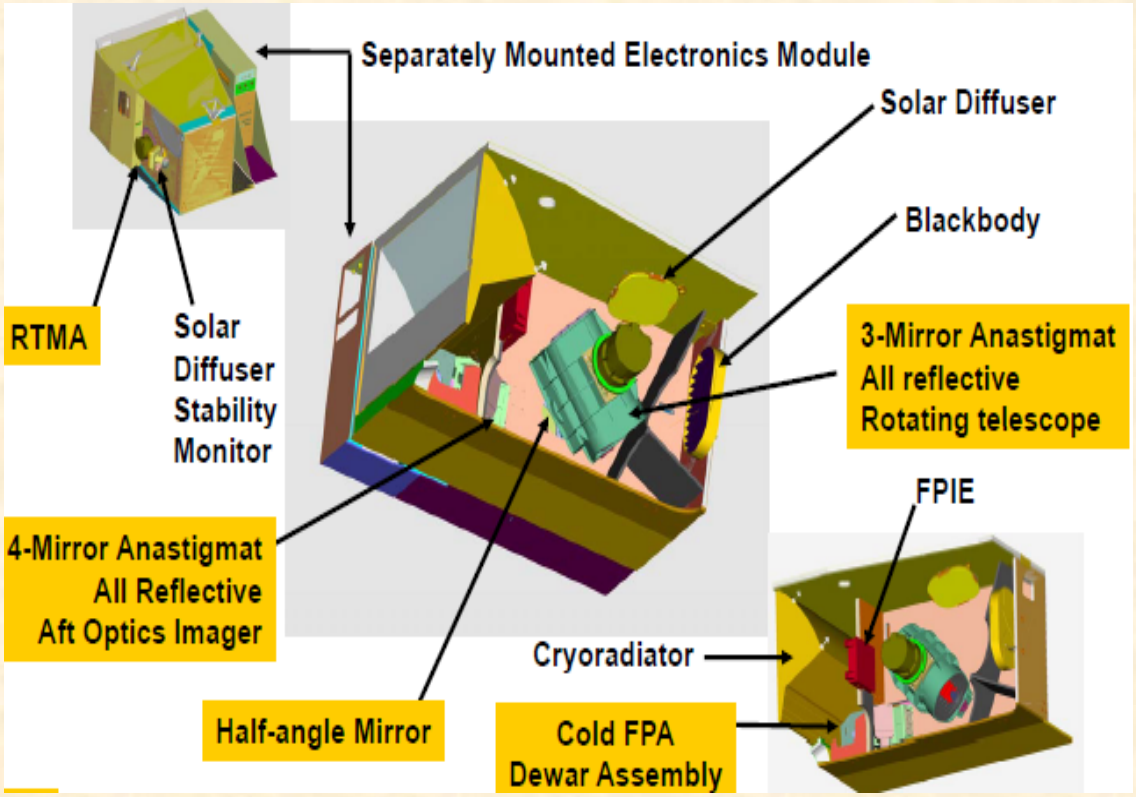
NOAA STAR JPSS Science Meeting 2017

14 August – 18 August 2017, College Park, MD

Outline

- Introduction
- Solar Diffusor Stability Monitor (SDSM) Calibration
- Solar Diffusor (SD) Calibration
- Lunar Calibration
- Hybrid Approach
- Inter-sensor and In-situ Comparison
- Ocean Color Products Performance
- Summary

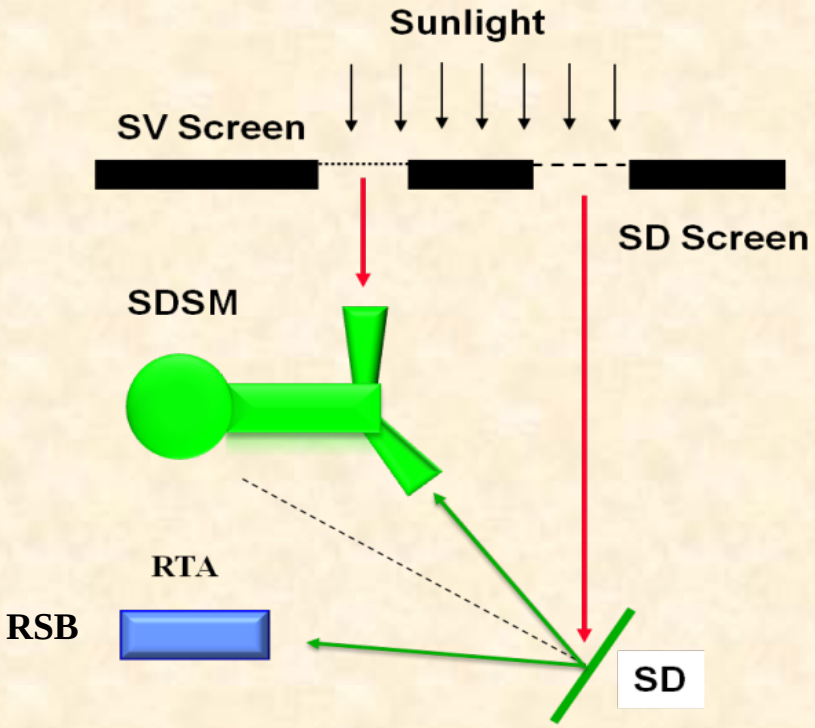
VIIRS Background



- *22 spectral bands - 410 nm to 12.013 μm spectral range*
- *14 Reflective Solar Bands (RSB) : 3 image bands, I1-I3, and 11 moderate bands, M1-M11*
- *The VIIRS RSB are calibrated on orbit by SD/SDSM calibration*
- *Monthly lunar observation through its space view (SV) since launch.*
- *For VIIRS, the angle of incidence (AOI) of the SV is exactly the same as that of the SD. Lunar observations should provide identical on-orbit gain change for VIIRS RSB as SD/SDSM calibration.*

VIIRS RSB uncertainty specification is 2%, but ocean color EDRs (using M1-M7, NIR; also M8, M10, and M11, NIR-SWIR; recently I1) need to achieve ~0.2%. This has been achieved.

SD/SDSM Calibration Overview



- *Key assumption: SD degrades uniformly with respect to both incident and outgoing directions*

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

- *SD and SDSM sun view screens:*
  - *Prevent RSB and SDSM saturation*
  - *Vignetting functions (VFs)*
  - *VFs measured prelaunch and validated by yaw measurements*
  - *SD bidirectional reflectance factors (BRFs)*
- *BRFs measured prelaunch and validated by yaw measurements*
  - *SD on-orbit degradation is tracked by the SDSM measurements at 8 wavelength from 412 nm to 935 nm*
- *SDSM measures H-factors*
- *F-factors, or RSB calibration coefficients, are the final calibration product*

SDSM Calibration Algorithm

- SDSM is a ratio radiometer, which views SD, Sun, and an internal dark scene successively in three-scan cycles.
- SD BRF for SDSM view direction

$$BRF_{SD,SDSM}(\lambda,t) = \rho_{SD,SDSM}(\lambda)H(\lambda,t)$$

  - $\rho_{SD,SDSM}(\lambda)$: Prelaunch BRF for SDSM view direction
  - $H(\lambda)$ is solar diffuser degradation since launch

- SD degradation, H factors, for SDSM view direction at the wavelength of the SDSM detector D

$$H(\lambda_D) = \left\langle \frac{dc_{SD,D}}{\rho_{SD,SDSM}(\lambda_D)\tau_{SDS}\cos(\theta_{SD})} \right\rangle_{Scan} \Bigg/ \left\langle \frac{dc_{SV,D}}{\tau_{SVS}} \right\rangle_{Scan}$$



SDSM operations: Every orbit first few months, then once per day for about two years, and once per two days since May, 2014.

- ***Improvements***
  - ***Robust and accurate VFs and BRFs from yaw measurements***
  - ***Ratio of the averages***
  - ***Sweet spots selection***

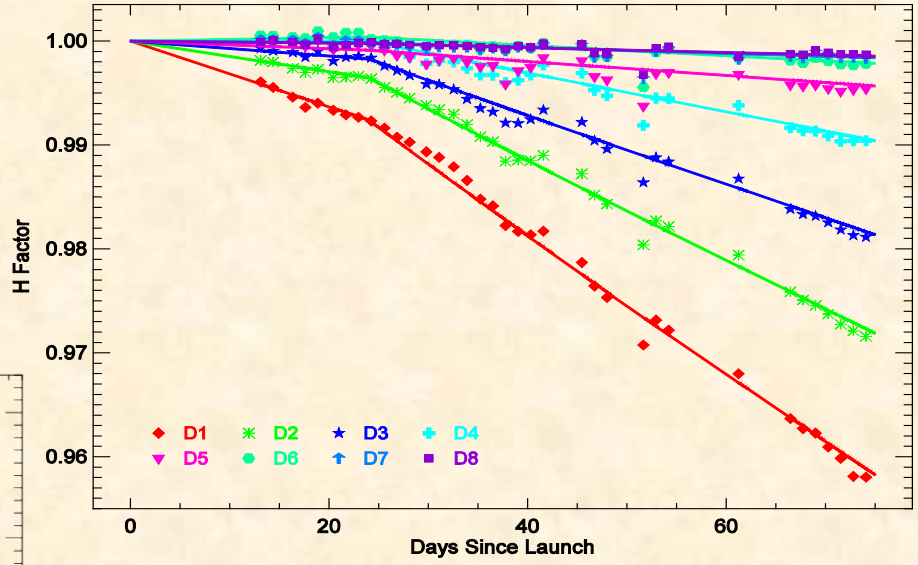
J. Sun and M. Wang, "Visible infrared image radiometer suite solar diffuser calibration and its challenges using solar diffuser stability monitor," Appl. Opt., 53, 8571-8584 (2014).

SDSM Calibration Performance

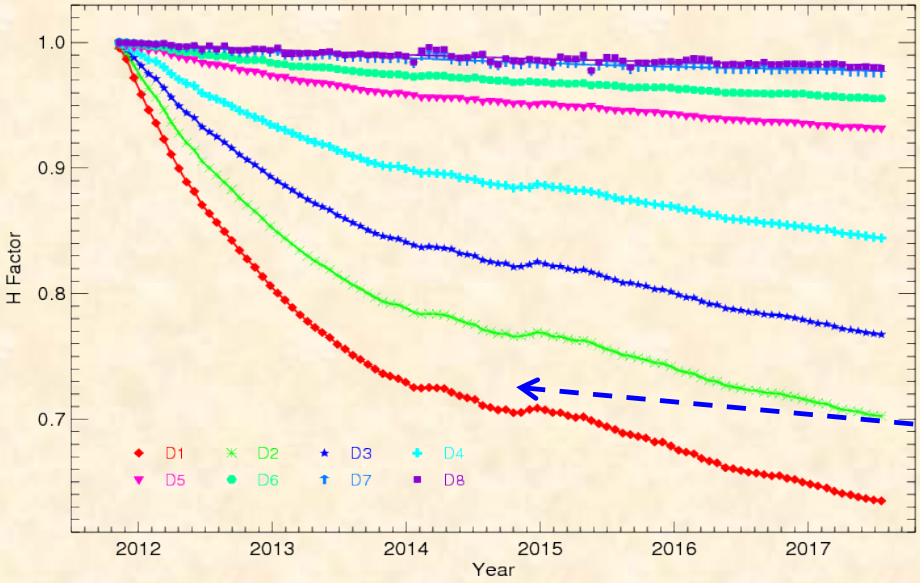
SD Degradation (H-Factors)

- ***Very stable***
- ***SDSM is very accurate!***
- ***Results are all actual measurements - No averaging over orbits, no smoothing, NO FANCY TRICKS***

SD Degradation – First 70 days



SD degradation



- ***First 25 days behaved differently.***
- ***But H-factor is in different direction from RSB view direction – KEY ISSUE***
- ***Unexpected but real degradation features (Nov 2014)***

SD Calibration Algorithm

- SD is made of Spectralon®, near Lambertian property



- Solar radinace reflected by the SD

$$L_{SD}(\lambda) = I_{Sun}(\lambda) \cdot \tau_{SDS} \cdot \cos(\theta_{SD}) \cdot \rho_{SD,RTA}(\lambda) \cdot h(\lambda) / d_{VS}^2$$

  - $\rho_{RSD,RTA}(\lambda)$: Prelaunch BRF for RTA view direction
  - $h(\lambda)$: SD degradation for SDSM view direction is used as the SD degradation for the RTA direction

SD Calibration: Every orbit

- RSB calibration coefficients, F factors

$$F(B,D,M,G) = \frac{RVS_{B,SD} \cdot \int RSR_B(\lambda) \cdot L_{SD}(\lambda) \cdot d\lambda}{\sum_i c_i(B,D,M,G) \cdot dn^i \cdot \int RSR_B(\lambda) \cdot d\lambda}$$

  - B, D, M, G: Band, Detector, HAM side, and gain status

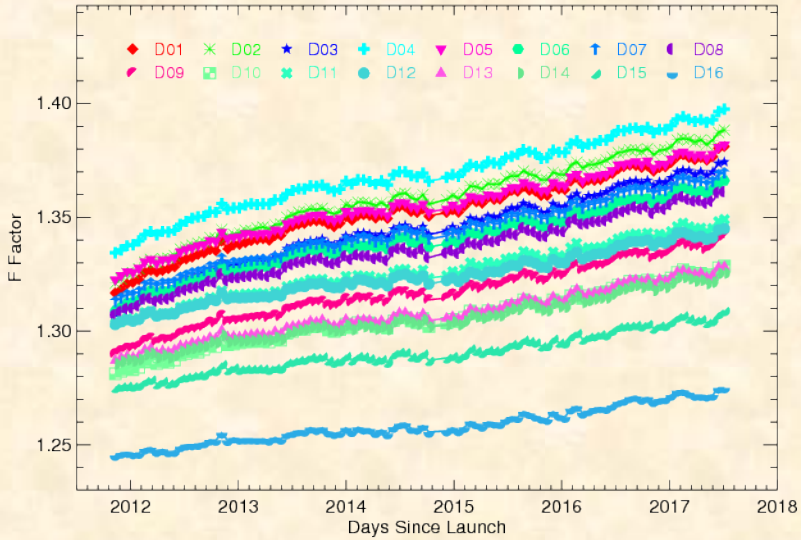
- ***Improvements***
  - ***Robust VFs and BRFs from yaw measurements***
  - ***Improved H factors***
  - ***Sweet spot selection***
  - ***Time-dependent RSR***

J. Sun and M. Wang, "On-orbit calibration of Visible Infrared Imaging Radiometer Suite reflective solar bands and its challenges using a solar diffuser," Appl. Opt., 54, 7210-7223 (2015).

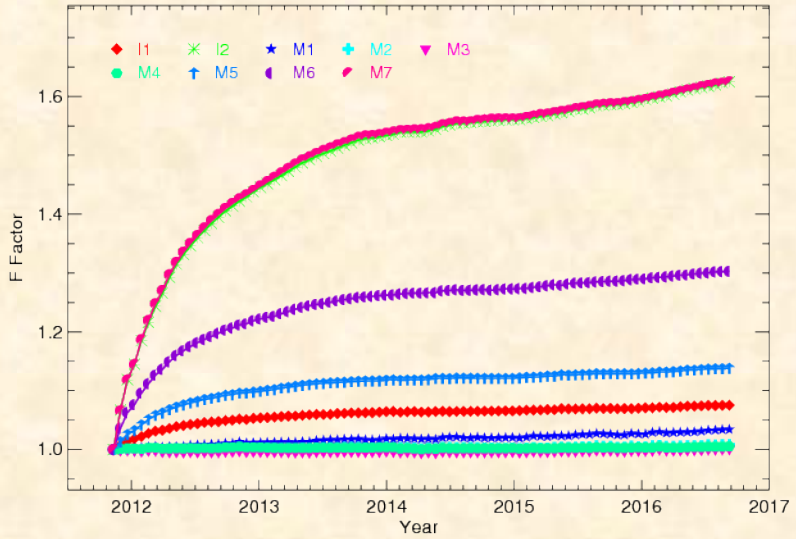
SD Calibration Performance

RSB Calibration Coefficients (SD F-Factors)

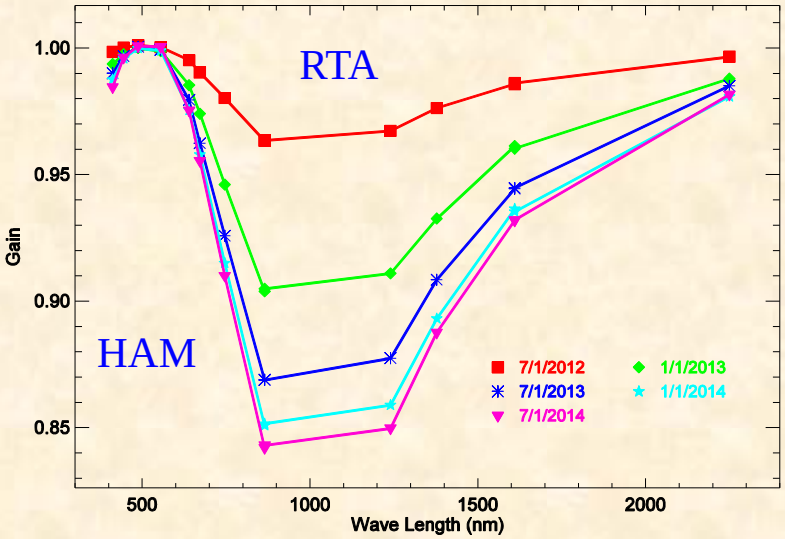
Band M1 HAM 1 HG F-factors



Band-averaged HAM 1 HG F-factors



On-orbit Gain Change



- ***Very stable and smooth***
- ***Different from MODIS: Much less degradation of the scan mirror***
- ***But the input H-factor measured by the SDSM is for the SDSM view direction – KEY ISSUE***

Lunar Calibration Algorithm

- Moon is very stable in its reflectance
- RSB calibration coefficients , F factors, from lunar observations

$$F(B,M) = \frac{g(B)N_{t,M}}{\sum_{D,S,N} L_{pl}(B,D,S,N)\delta(M,M_N)},$$

  - *g(B)*: View geometric effect correction (ROLO lunar model and extra correction)

SNPP VIIRS is scheduled to view the Moon approximately monthly (about nine months every year)



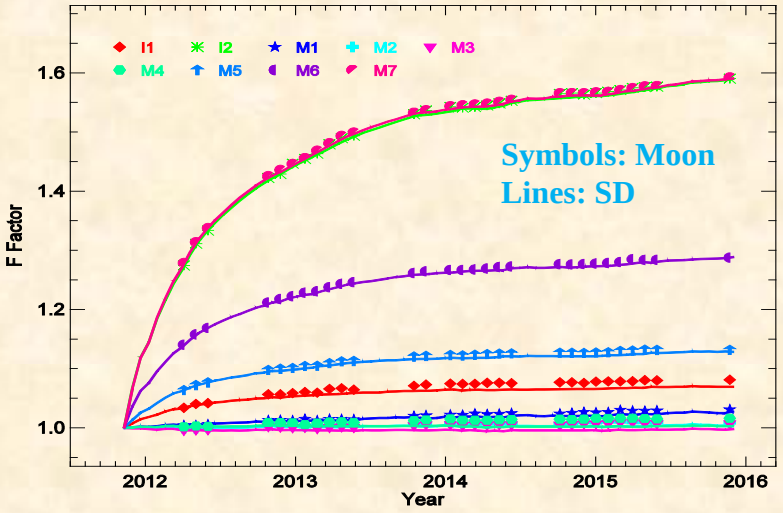
- ***Advantages***
  - ***Lunar surface reflectance has no observable degradation***
  - ***Can be used for inter-comparison***

J. Sun, X. Xiong, and J. Butler, "NPP VIIRS on-orbit calibration and characterization using the moon", Proc. SPIE, 8510,85101I, (2012).
X. Xiong, J. Sun, J. Fulbright, Z. Wang, and J. Butler, "Lunar Calibration and Performance for S-NPP VIIRS reflective Solar Bands", IEEE Trans. Geosci. Remote Sens., **54**, 1052-1061, (2016).

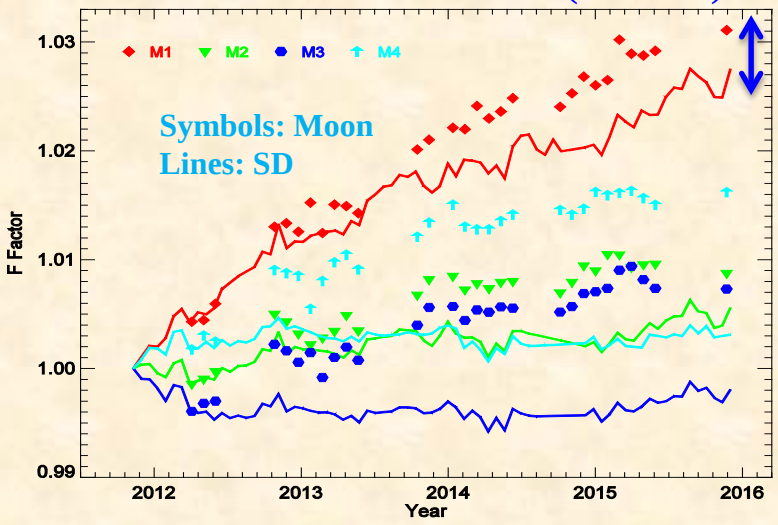
Lunar Calibration Performance

RSB Calibration Coefficients (Lunar F-Factors)

Lunar and SD F Factors

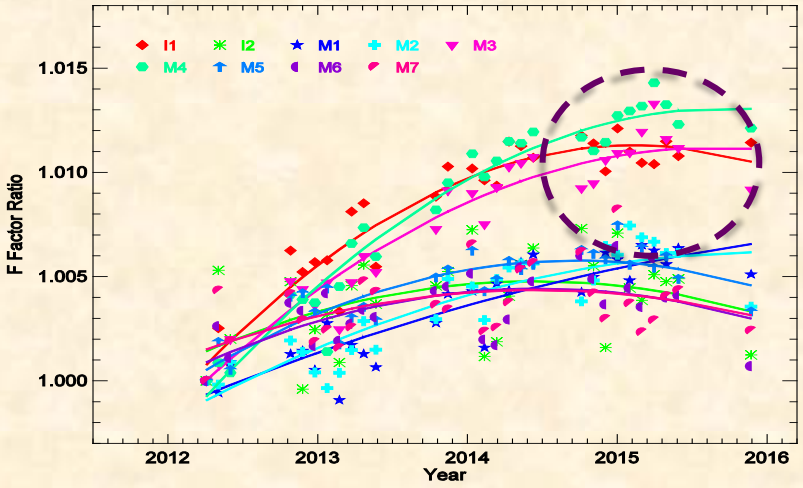


Lunar and SD F factors (M1-M4)



Ex: Relative Bias

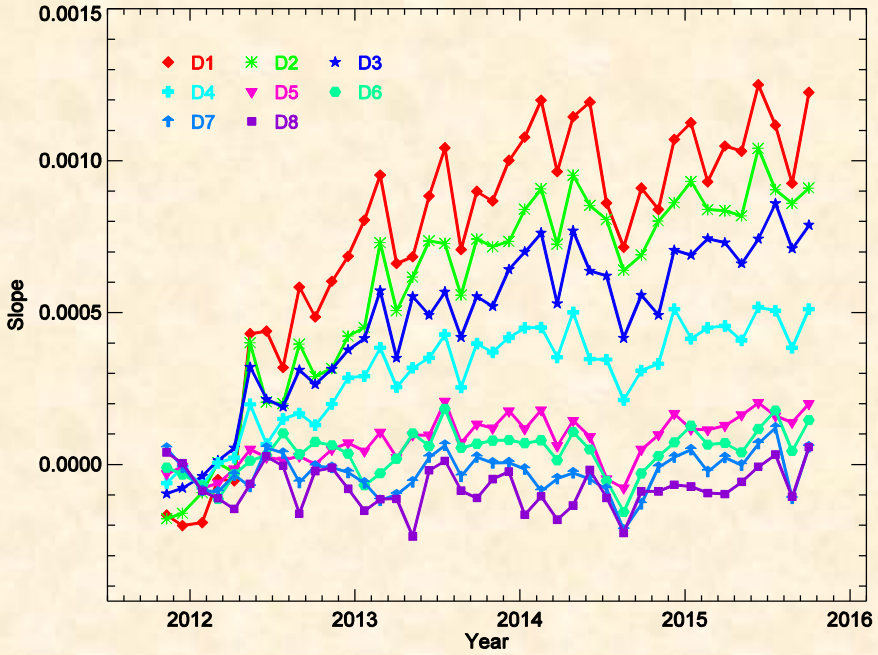
Calibration coefficients Ratios



- ***Own Lunar model and correction beyond ROLO model***
- ***New Lunar results much improved – smooth, no oscillation - 0.2% stability***
- ***SD F-factors and lunar F-factors diverge, especially for short wavelength RSBs.***
- ***SD F-factors have error***

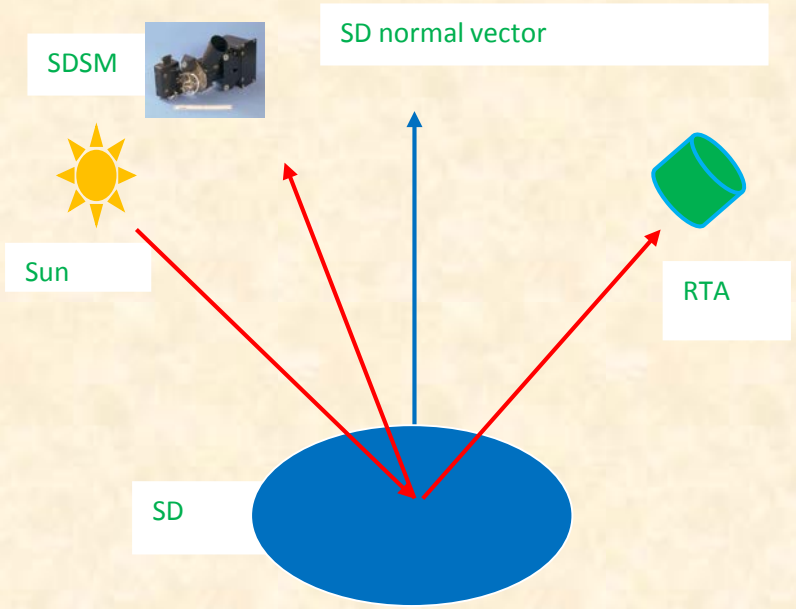
Non-Uniformity of the SD Degradation

Non-uniformity of SD degradation



Slopes of H-factors in each individual event with respect to solar declination

SDSM and RTA views



- It was discovered by 2014 that SD degradation is not uniform
- Standard SD calibration brings non-negligible error into RSB characterization

J. Sun, M. Chu, M. Wang, "Degradation nonuniformity the solar diffuser bidirectional reflectance distribution factor," Appl. Opt., 55, 6001-6016 (2016).

Hybrid Approach

- SD Calibration
  - SD degrades non-uniformly, resulting long-term drifts
  - Results are stable and smooth
  - Observation in every orbit
- Lunar Calibration
  - No degradation issue
  - Infrequent and no observation in three months every year

F-Factors Ratios are fitted to quadratic polynomials of time

- **Hybrid Approach**

$$\mathcal{F}(B,D,M,G) = R(B,t)\cdot F(B,D,M,G)$$

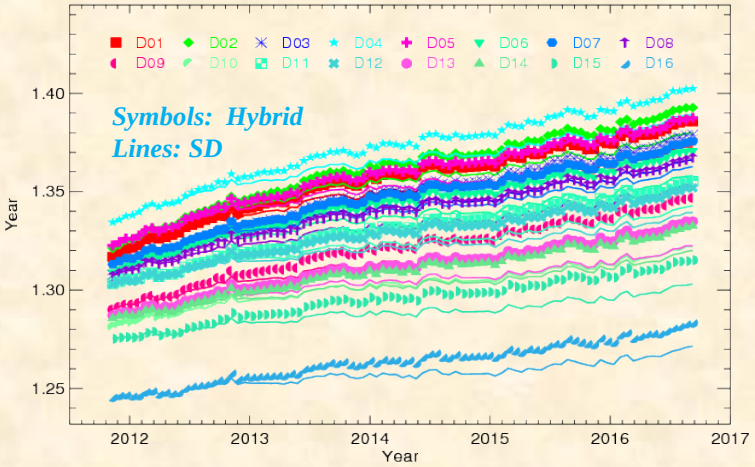
$$R(B,t) = \left\langle f(B,M,t)\right\rangle_{M} / \left\langle F(B,D,M,0,t)\right\rangle_{D,t-15<t_i<t+15,M}$$

  - **Lunar calibration provides long-term baseline**
  - **SD calibration provides smoothness and frequency**

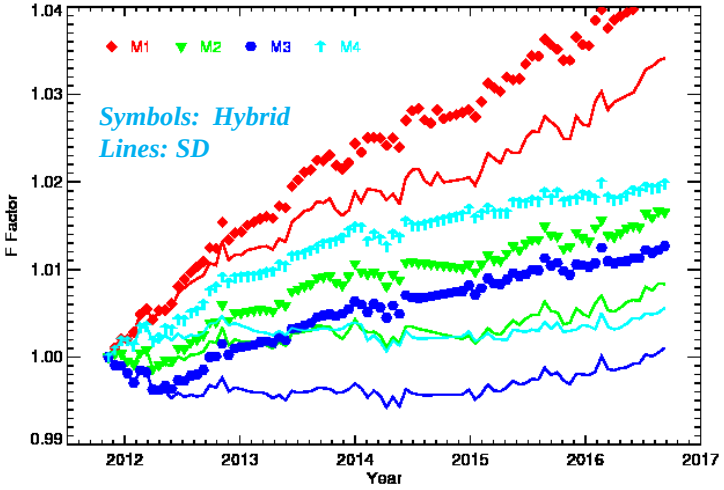
J. Sun and M. Wang, "Radiometric Calibration of the VIIRS Reflective Solar Bands with Robust Characterizations and Hybrid Calibration Coefficients," Appl. Opt., 54, 9331-9342 (2015).

Hybrid Calibration Performance

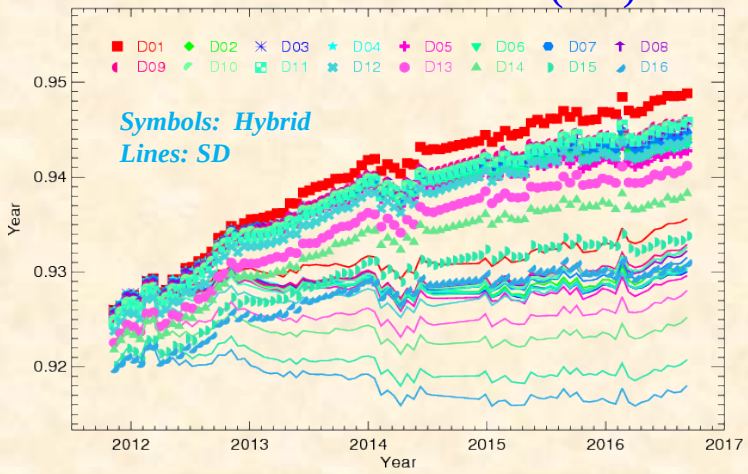
Calibration Coefficients (M1)



Band Averaged (M1-M4)



Calibration Coefficients (M4)

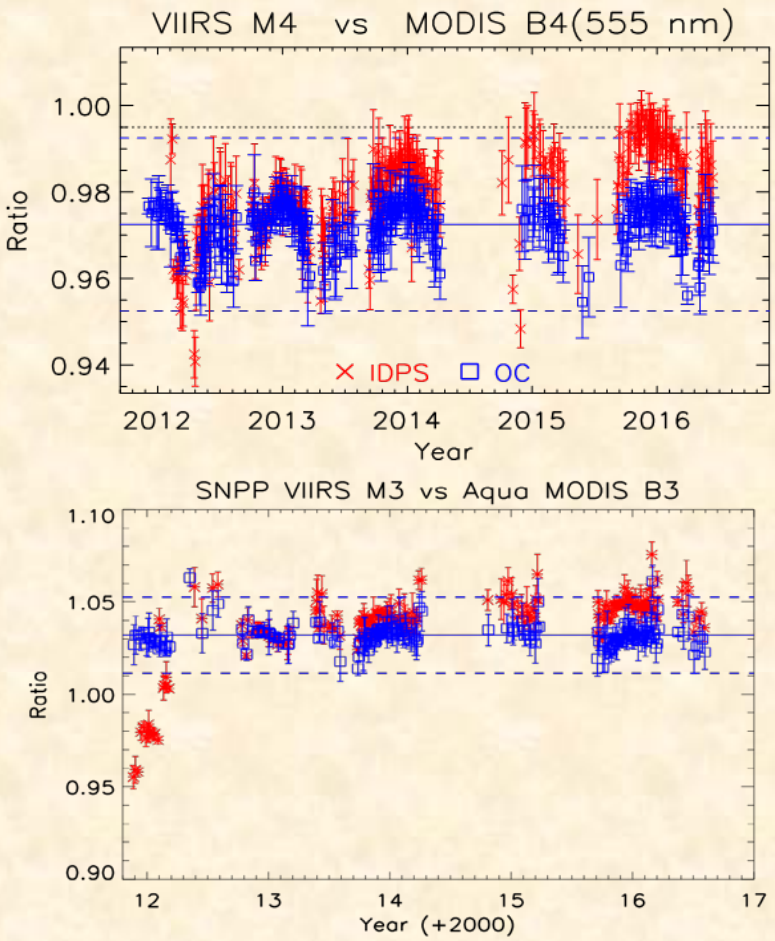


- Hybrid calibration coefficients (Hybrid F-factors) achieves long-term accuracy but also with short-term stability achieving ~0.2% level.
- Earth-based SDR studies show that Hybrid-method indeed mitigated the long-term defect and give stable time-series.

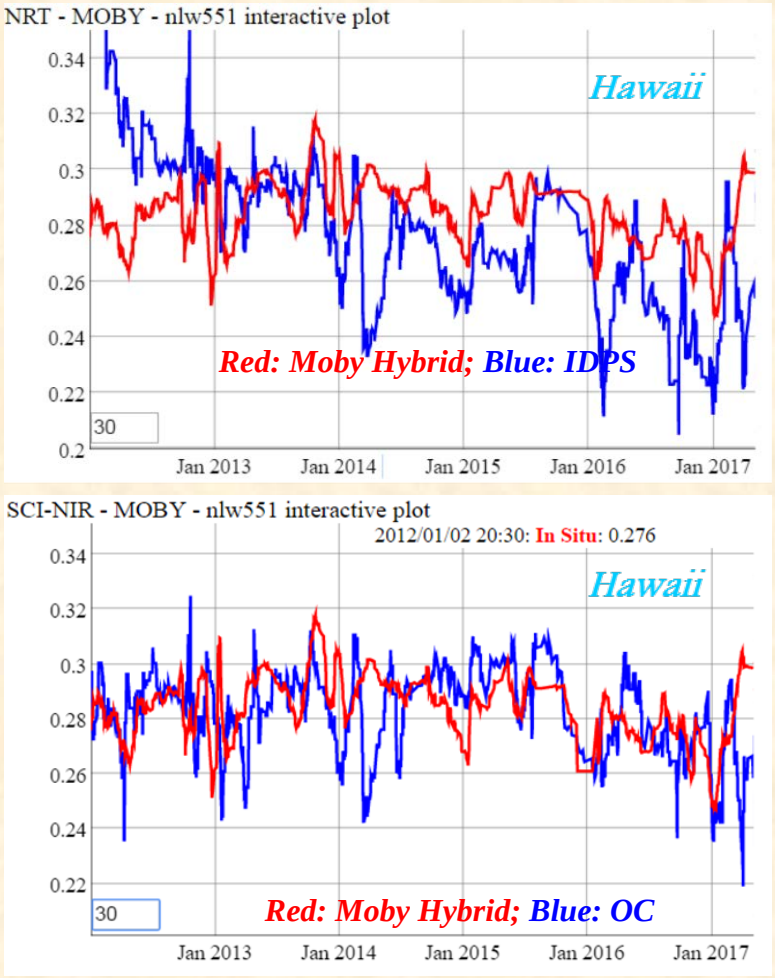
J. Sun and M. Wang, "VIIRS Reflective Solar Bands Calibration Progress and Its Impact on Ocean Color Products," Remote Sensing, 8, 194 (2016).

Inter-sensor and In-situ Comparison

Aqua MODIS and VIIRS Radiance SNO Ratio



Water Leaving Radiance: nLw(551), M4

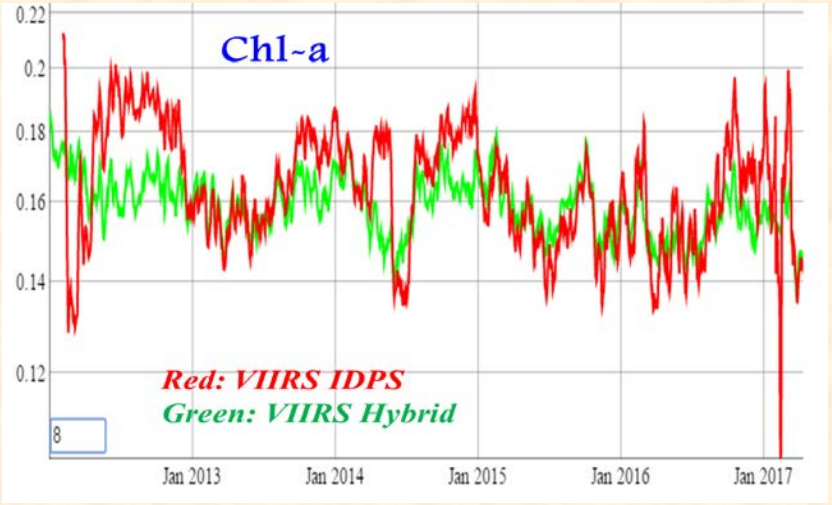


Chu, M., J. Sun, and M. Wang, "Radiometric evaluation of the SNPP VIIRS RSB sensor data records via inter-sensor comparison with Aqua MODIS", Proc. SPIE 9972, 99721R (2016).

Ocean Color Products Performance

Global Deep Water (Depth > 1km)









M. Wang, et al, "Evaluation of VIIRS ocean color products," Proc. SPIE 9261, 92610E (2014).

Charts were produced by X. Liu and S. Son.

Summary

- Very rigorous RSB calibration has been achieved and demonstrated.
- “Hybrid-method” mitigation is the primarily important correction that removes the long-term worsening bias coming from within SD calibration at the SDR level.
- With our hybrid F-factor look-up-tables (LUTs), both the reprocessed mission-long and forward real-time VIIRS Ocean Color EDR products demonstrate very high quality performance.
- Forward delivery of publicly accessible science quality EDR with the hybrid F-factor LUTs has been implemented since May 2016.
- **Our hybrid F-factor LUTs for all RSB have been adopted for the official operational VIIRS SDR reprocessing (as an option for high quality science quality EDRs).**
- **Per request, our hybrid F-factor LUTs have also been sent to NASA Ocean Biology and Biogeochemistry Program Group (OBPG) for their testing and processing.**

Backup

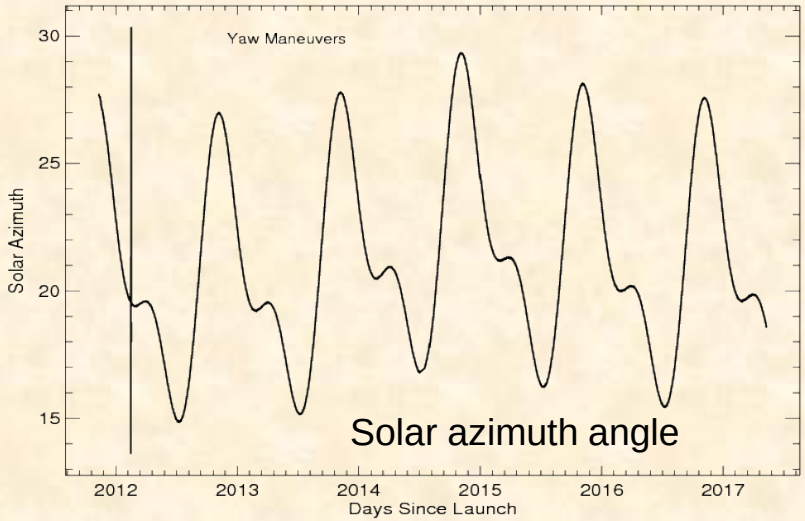
Table 1. Specification for SNPP VIIRS RSBs and SDSM detectors.

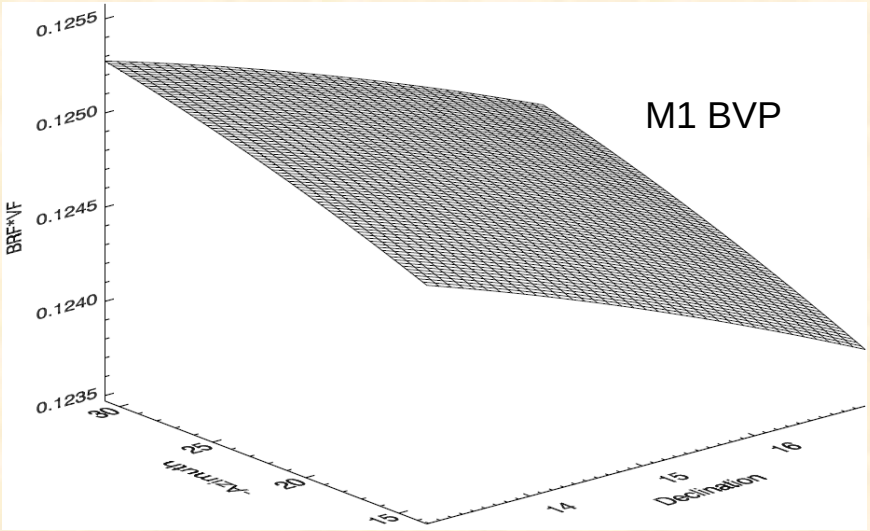
VIIRS Band	CW* (nm)	Band Gain	Detectors	Resolution*	SDSD Detector	CW* (nm)
M1	410	DG	16	742m x 776m	D1	412
M2	443	DG	16	742m x 776m	D2	450
M3	486	DG	16	742m x 776m	D3	488
M4	551	DG	16	742m x 776m	D4	555
I1	640	SG	32	371m x 387m	NA	NA
M5	671	DG	16	742m x 776m	D5	672
M6	745	SG	16	742m x 776m	D6	746
M7	862	DG	16	742m x 776m	D7	865
I2	862	SG	32	371m x 387m	D7	865
NA	NA	N	16		D8	935
M8	1238	SG	16	742m x 776m	NA	NA
M9	1378	SG	16	742m x 776m	NA	NA
M10	1610	SG	16	742m x 776m	NA	NA
I3	1610	SG	32	371m x 387m	NA	NA
M11	2250	SG	16	742m x 776m	NA	NA

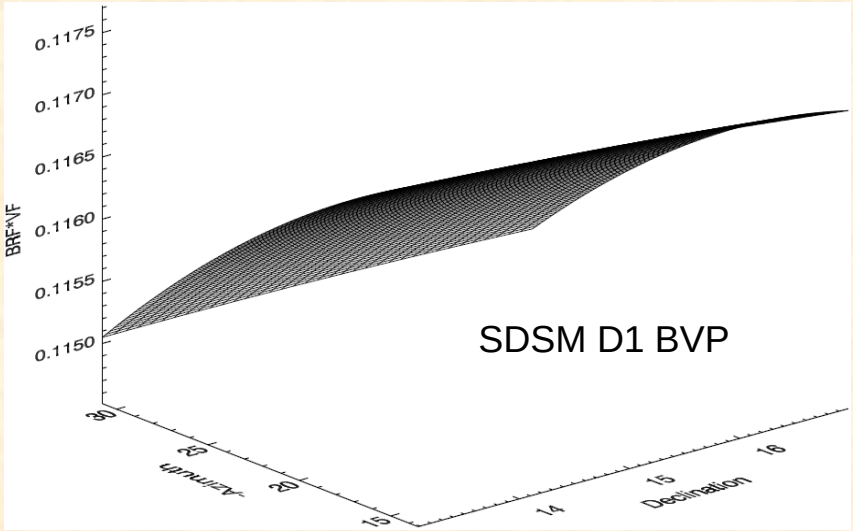
*CW: Center Wavelength; DG: Dual Gain; SG: Singla Gain; Resolution: Track x Scan at Nadir after aggregation

SD BRF and SDS VF

BRF-VF Product (BVP)





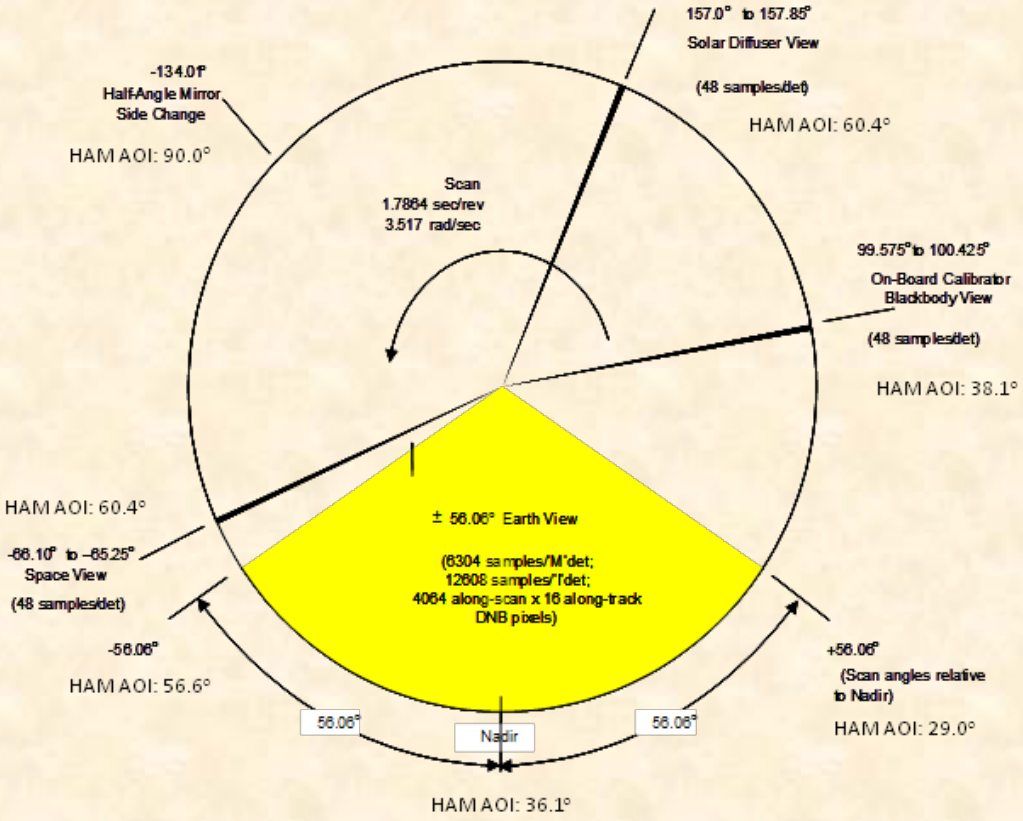


- Yaw carefully planned, cover all solar angle range for SD/SDSM calibration.
- Carefully derive BRFs and VFs from the yaw measurements is the crucial 1st step.
- **Need to do it right just one time from yaw data.**

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

RSB On-Orbit Calibration

- 22 spectral bands - 410 nm to 12.013 μm spectral range
- 14 Reflective Solar Bands (RSB) : 3 image bands, I1-I3, and 11 moderate bands, M1-M11
- The VIIRS RSB are calibrated on orbit by SD/SDSM calibration
- Monthly lunar observation through its space view (SV) since launch.
- For VIIRS, the angle of incidence (AOI) of the SV is exactly the same as that of the SD. Lunar observations should provide identical on-orbit gain change for VIIRS RSB as SD/SDSM calibration.



VIIRS RSB uncertainty specification is 2%, but ocean color EDRs (using M1-M7, NIR; also M8, M10, and M11, NIR-SWIR; recently I1) need to achieve ~0.2%. This has been achieved.

Reconstruction of Missing Data in the VIIRS Global Ocean Color Images Using the DINEOF Method

Xiaoming Liu and Menghua Wang

VIIRS Ocean Color EDR Team

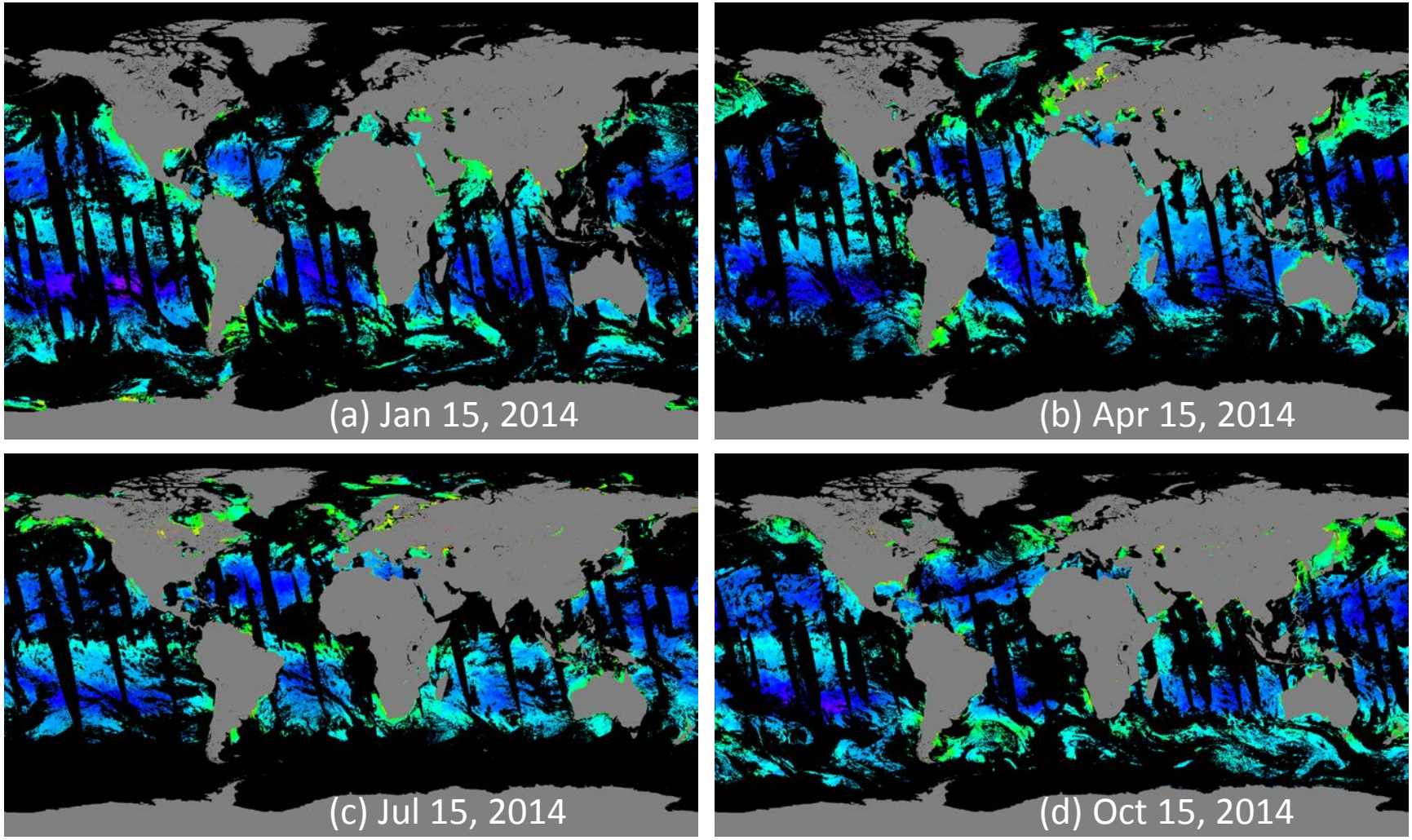
NOAA/NESDIS Center for Satellite Applications and Research (STAR)

JPSS Annual Science Team Meeting, College Park, MD, August 14-18, 2017

Introduction

- Visible Infrared Imaging Radiometer Suite (VIIRS) ocean color images, such as normalized water-leaving radiances $nL_w(\lambda)$, chlorophyll-a (Chl-a) concentrations, and the water diffuse attenuation coefficient at the wavelength of 490 nm ($K_d(490)$) (*Wang et al.*, 2013), are very useful for monitoring and understanding coastal biological and ecological processes and phenomena. However, there are lots of missing pixels in the ocean color images due to clouds and various other reasons.
- The Data Interpolating Empirical Orthogonal Function (**DINEOF**) is a method to reconstruct missing data in geophysical datasets based on Empirical Orthogonal Function **(EOF)**. It utilizes both temporal and spatial coherencies of data to infer a solution at the missing locations (*Alvera-Azcarate et al.*, 2005). In this study, the DINEOF is used to fill up gap pixels in the VIIRS global daily, 8-day, and monthly composite ocean color images.

VIIRS Original Daily Chl-a Images

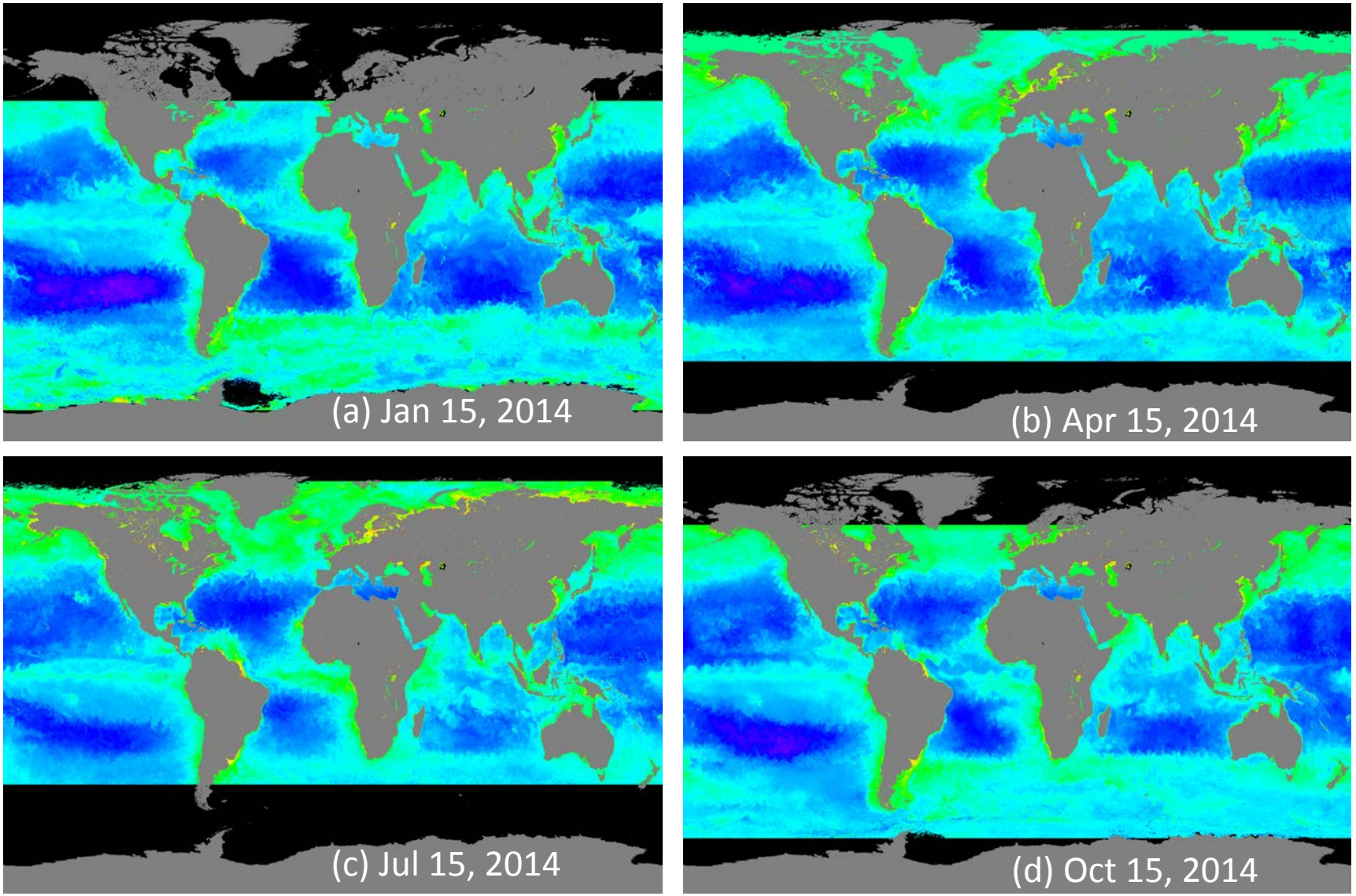


Original VIIRS daily Chl-a for (a) Jan. 15, (b) Apr. 15, (c) Jul. 15 and (d) Oct. 15, 2014, generated from VIIRS global daily Level-3 binned file.

Reconstruct Global Daily Data Using DINEOF

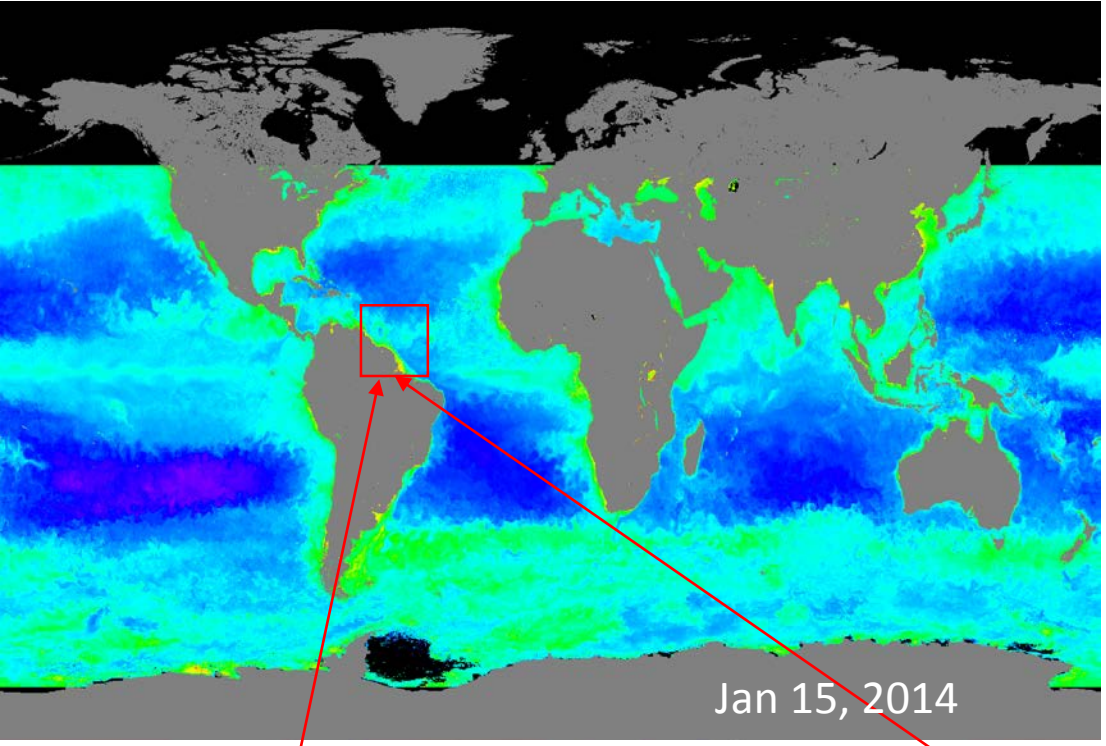
- Input: Global daily Level-3 binned data file in Jan, Apr, Jul and Oct 2014.
- To increase DINEOF performance, global data are divided into 16 zonal sections: 80°S-70°S, 70°S-60°S, … 10°S-Equator, Equator-10°N, 10°-20°N, … 60°-70°N, 70°-80°N.
- Replace pixels that are missing for the whole month with climatology value.
- Apply DINEOF on each of the 16 zonal sections, fully reconstruct all pixels, including non-missing pixels.
- Output: Fully reconstructed global daily Level-3 binned data.

Fully Reconstructed Daily Chl-a Images

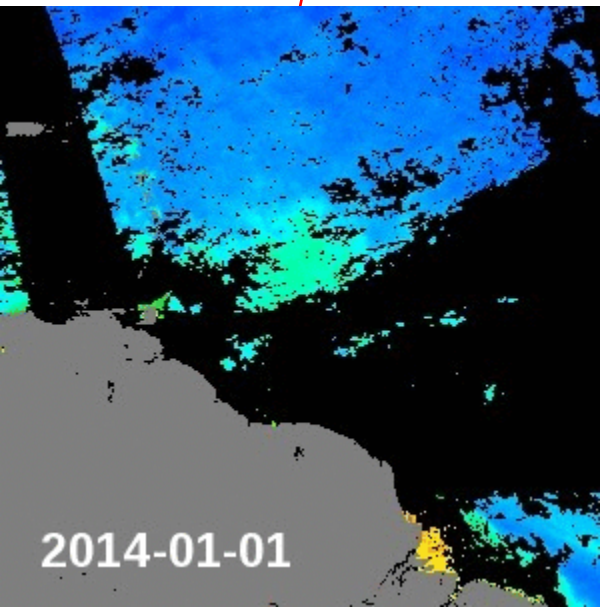


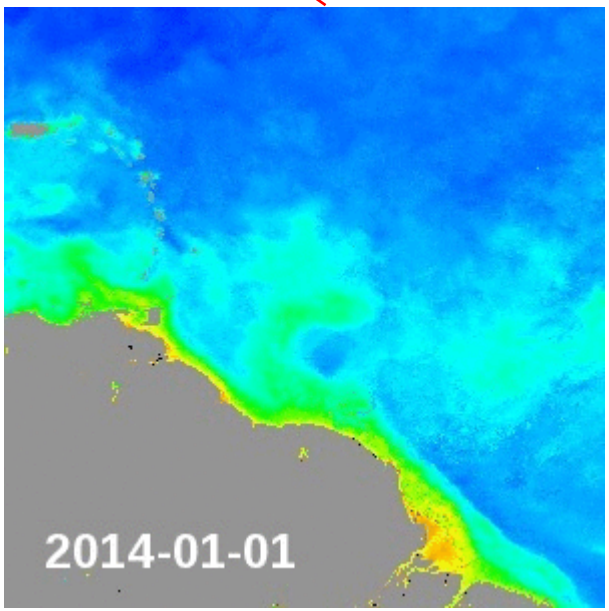
Fully reconstructed daily Chl-a for (a) Jan. 15, (b) Apr. 15, (c) Jul. 15, and (d) Oct. 15, 2014.

Examples of Reconstructed Chl-a Images (1)



Eddies near Amazon River
January 1-31, 2014

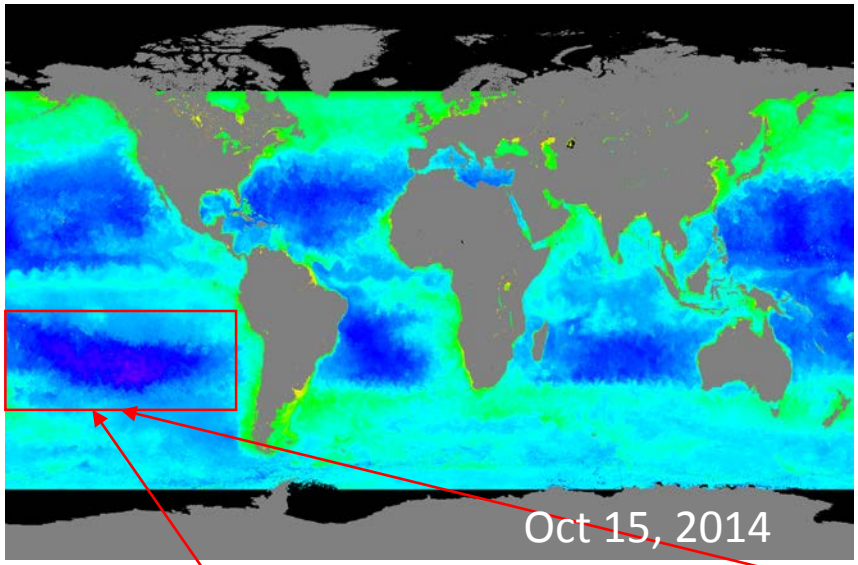




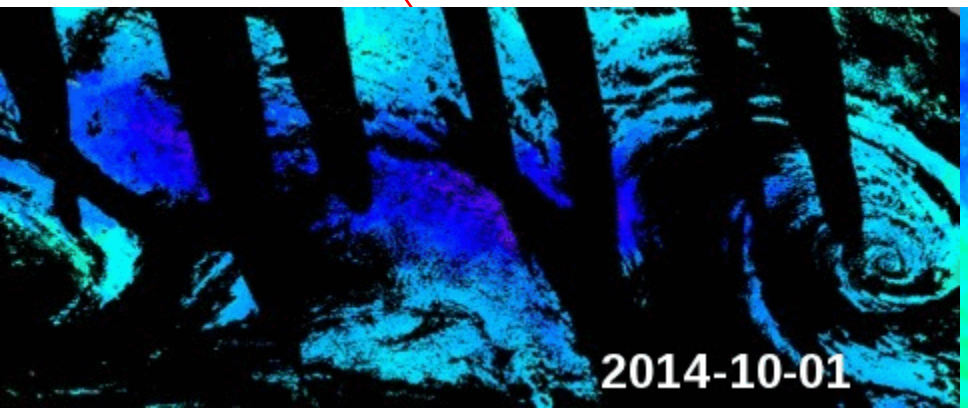
Original **Reconstructed**

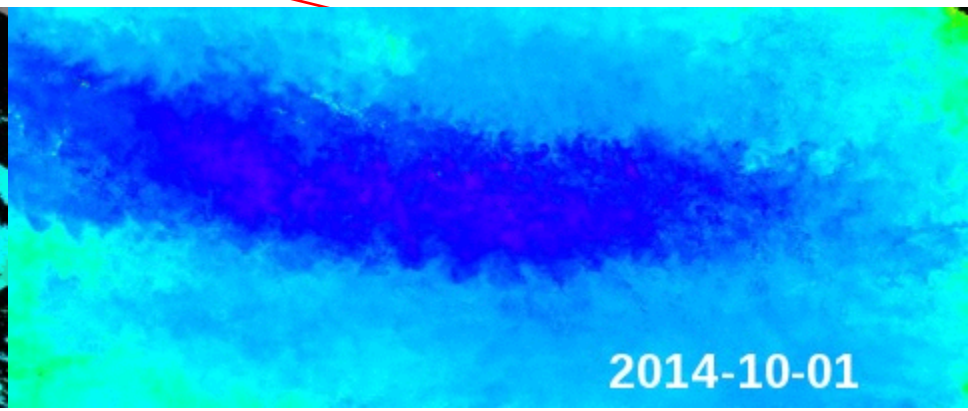
We can now see **eddy movement** in the reconstructed Chl-a images

Examples of Reconstructed Chl-a Images (2)



South Pacific Gyre
Oct. 1-31, 2014



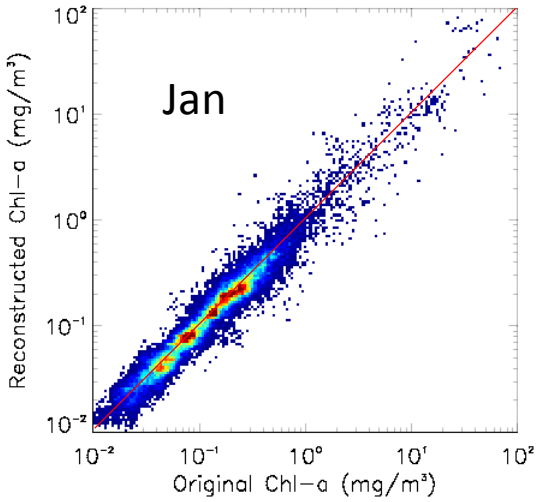


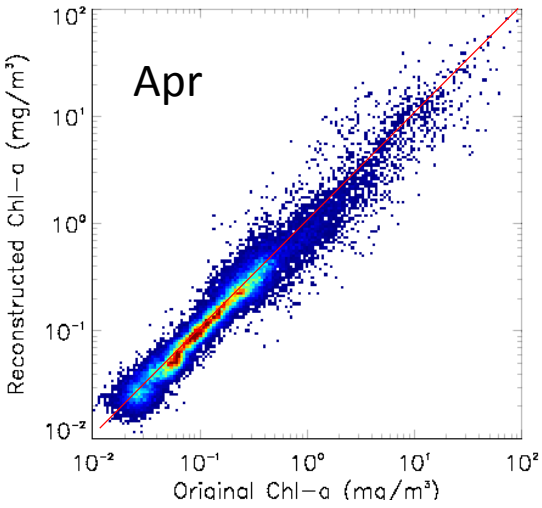
Original

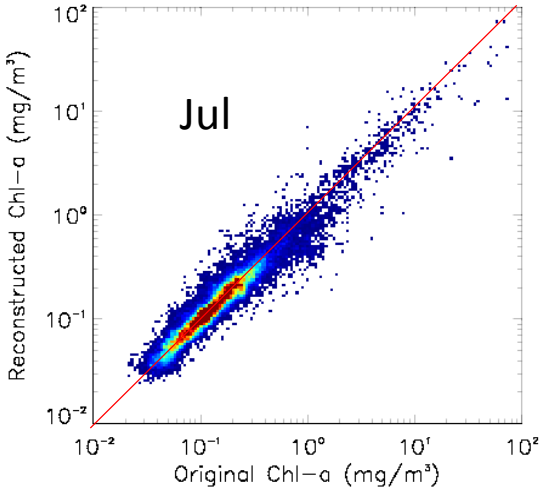
Reconstructed

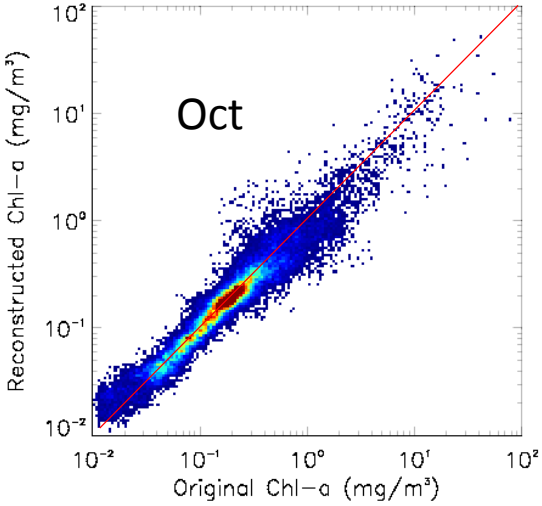
We can now see Gyre coverage variation in the reconstructed Chl-a images

Validation with 5% valid pixels





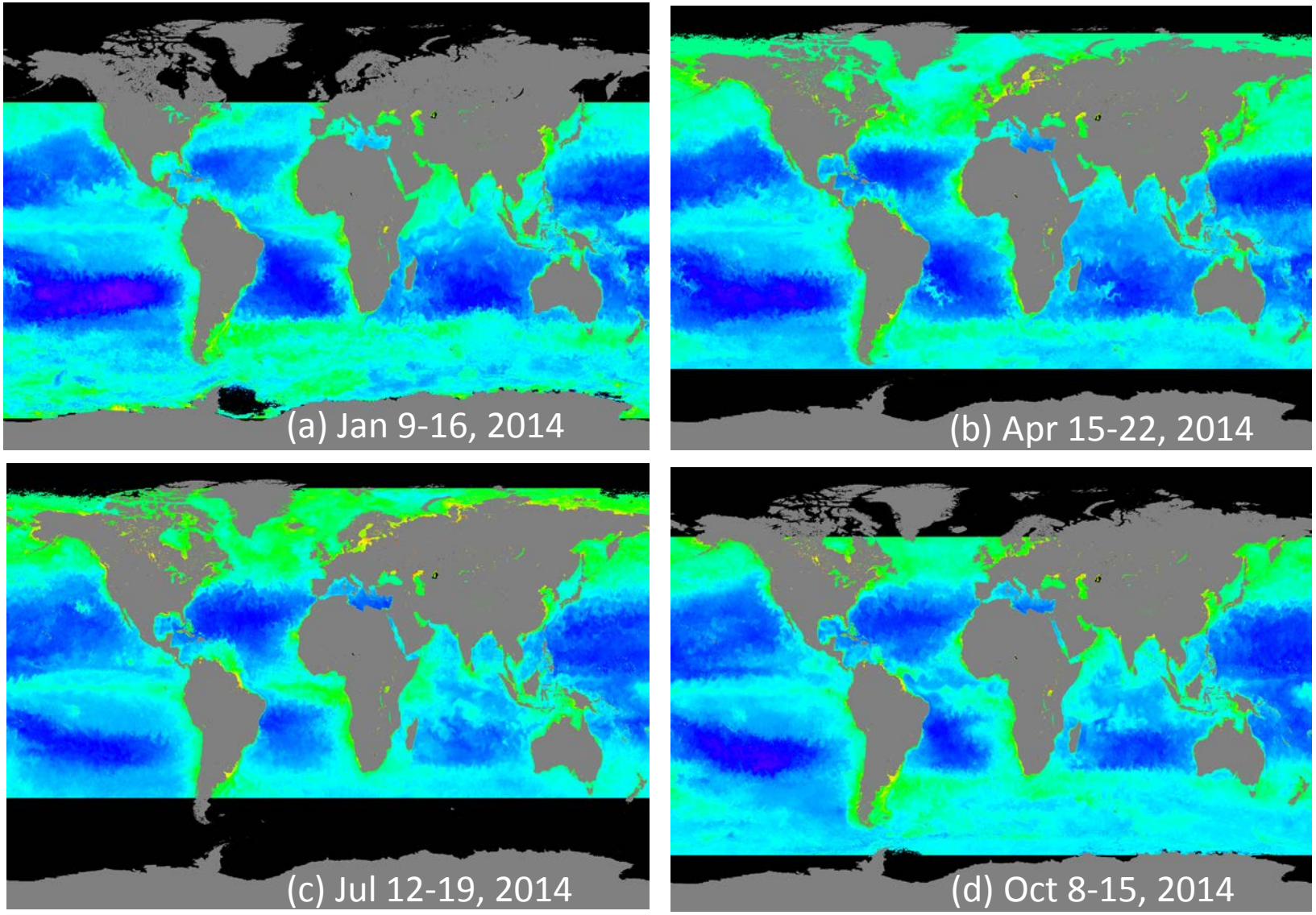




Reconstructed/original ratio

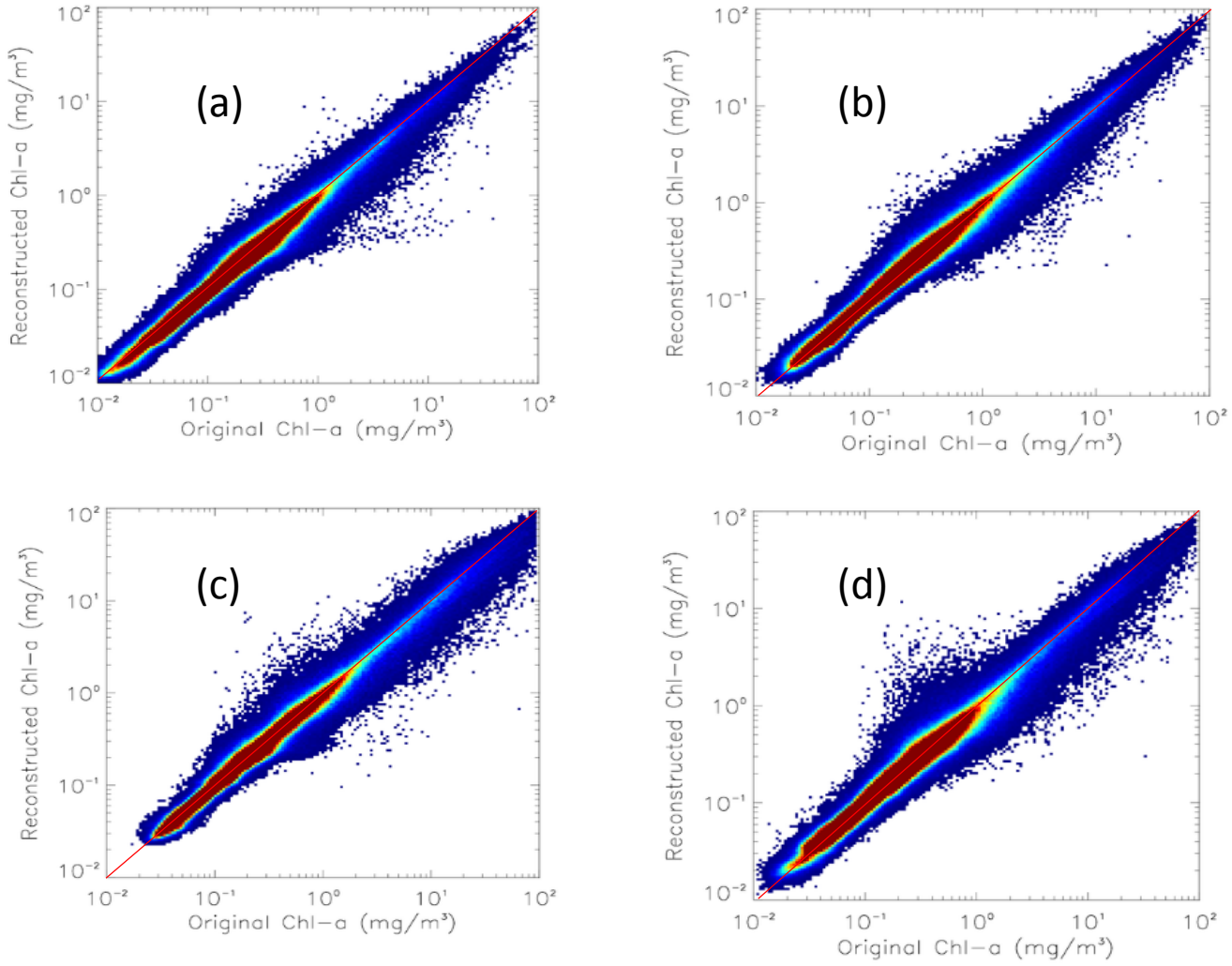
Month	Mean	Median	STD
Jan	1.022	0.996	0.261
Apr	1.033	0.996	0.319
Jul	1.015	0.986	0.246
Oct	1.021	0.985	0.354

Reconstruct Global 8-Day Data Using DINEOF



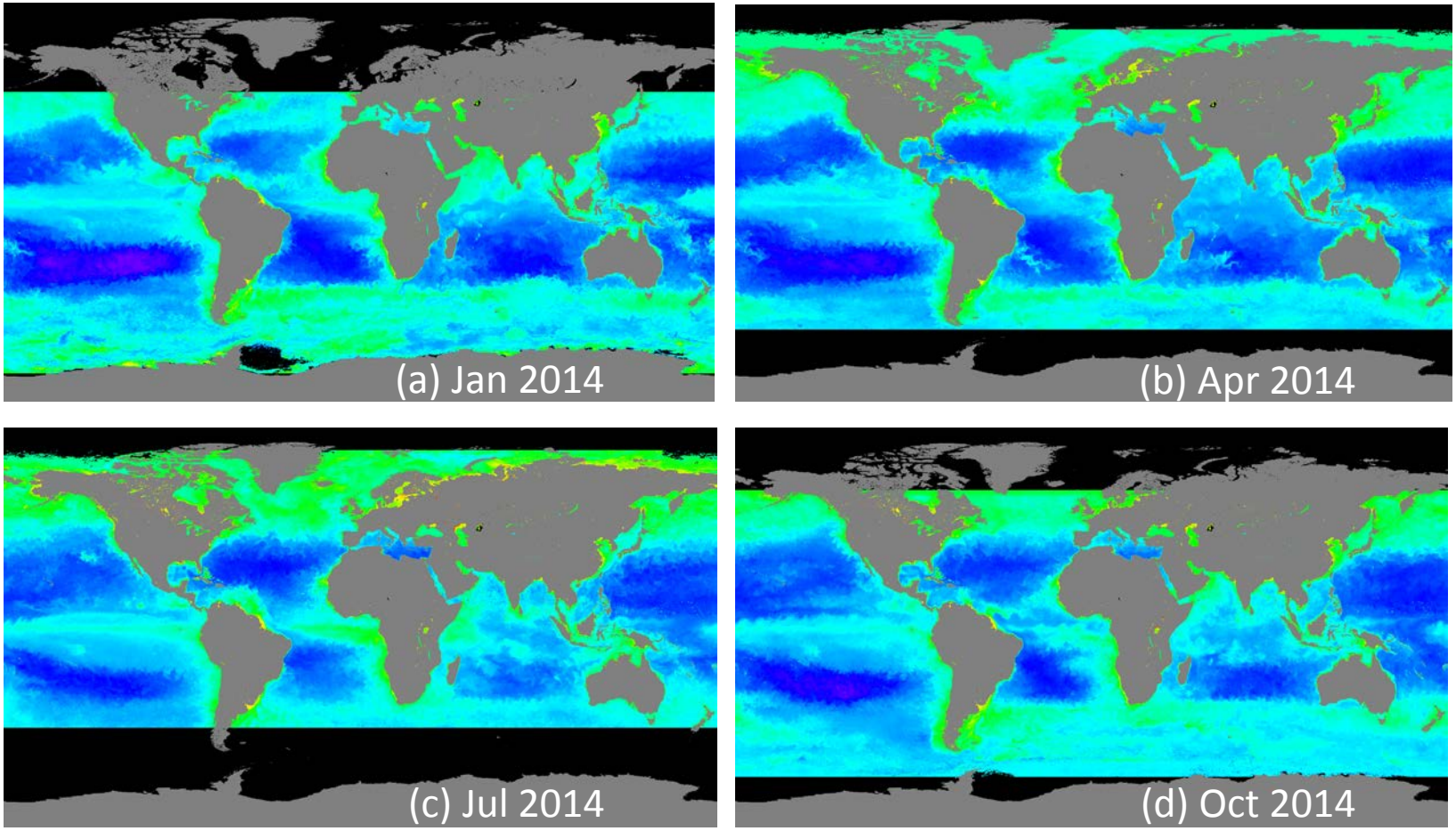
Reconstructed 8-day Chl-a for (a) Jan. 15, (b) Apr. 15, (c) Jul. 15, and (d) Oct. 15, 2014.

Validations and Evaluations



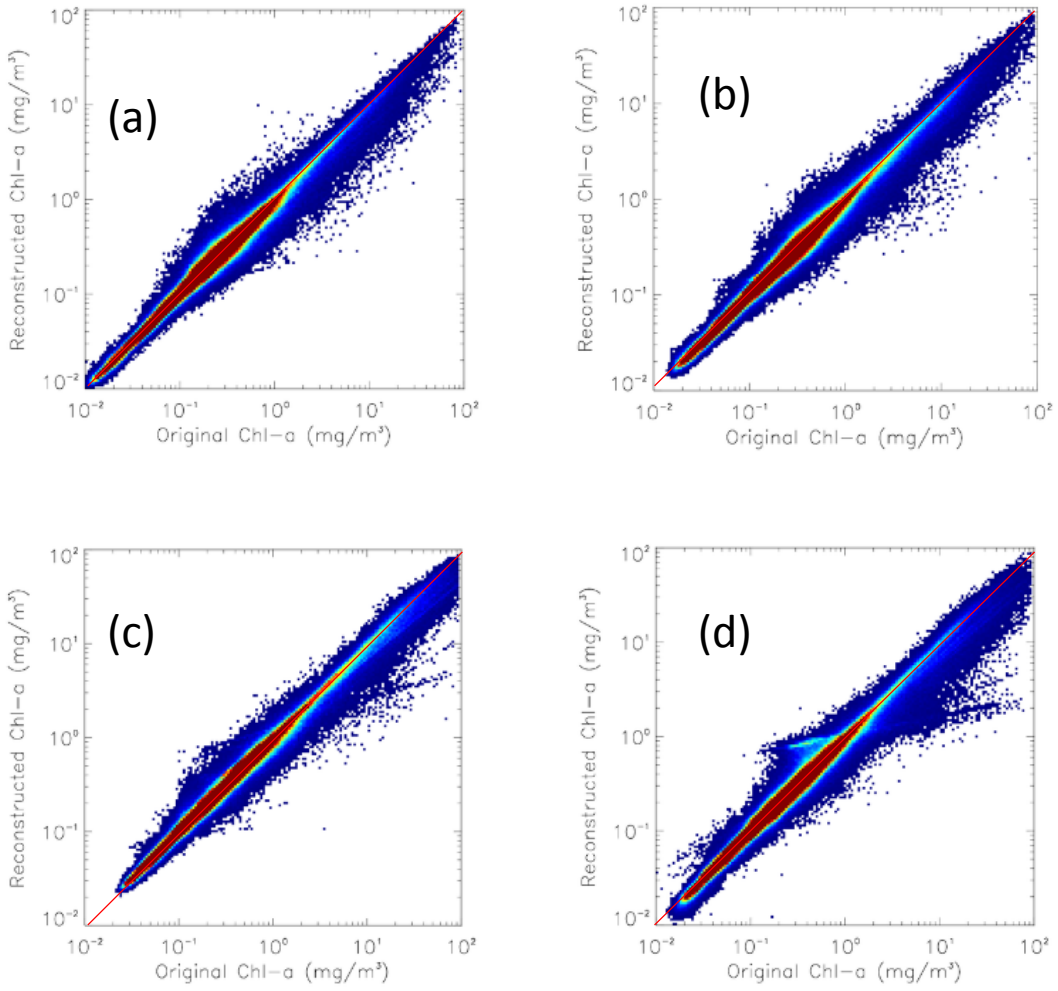
Scatter plot of reconstructed vs. original 8-day Chl-a for (a) Jan. 9-16, (b) Apr. 15-22, (c) Jul. 12-19, and (d) Oct. 8-15, 2014

Reconstruct Global Monthly Data Using DINEOF



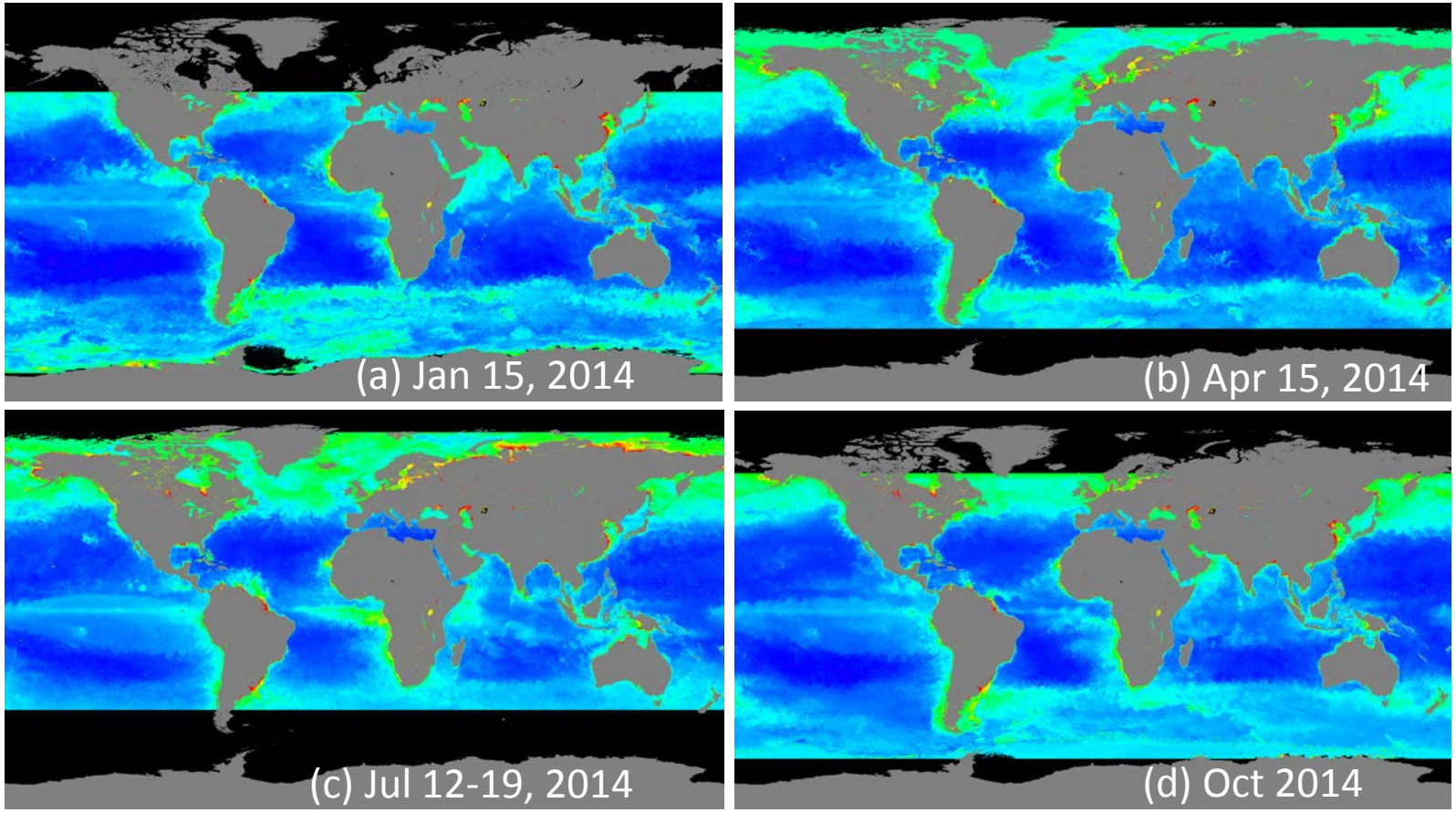
Reconstructed monthly Chl-a for (a) Jan., (b) Apr., (c) Jul., and (d) Oct. 2014.

Validations and Evaluations



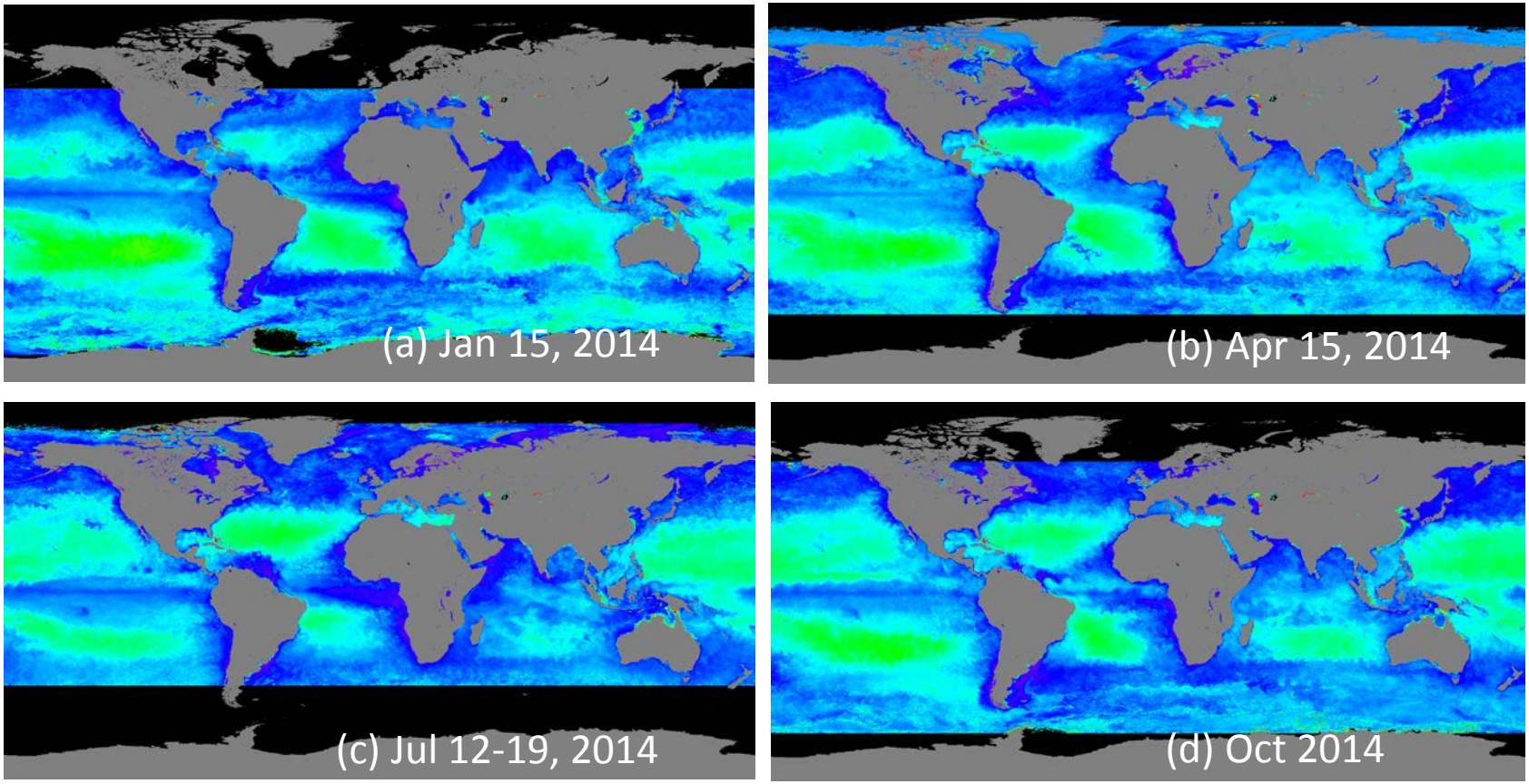
Monthly scatter plot for (a) Jan., (b) Apr., (c) Jul., and (d) Oct. 2014

Reconstruct Global $K_d(490)$ Data Using DINEOF



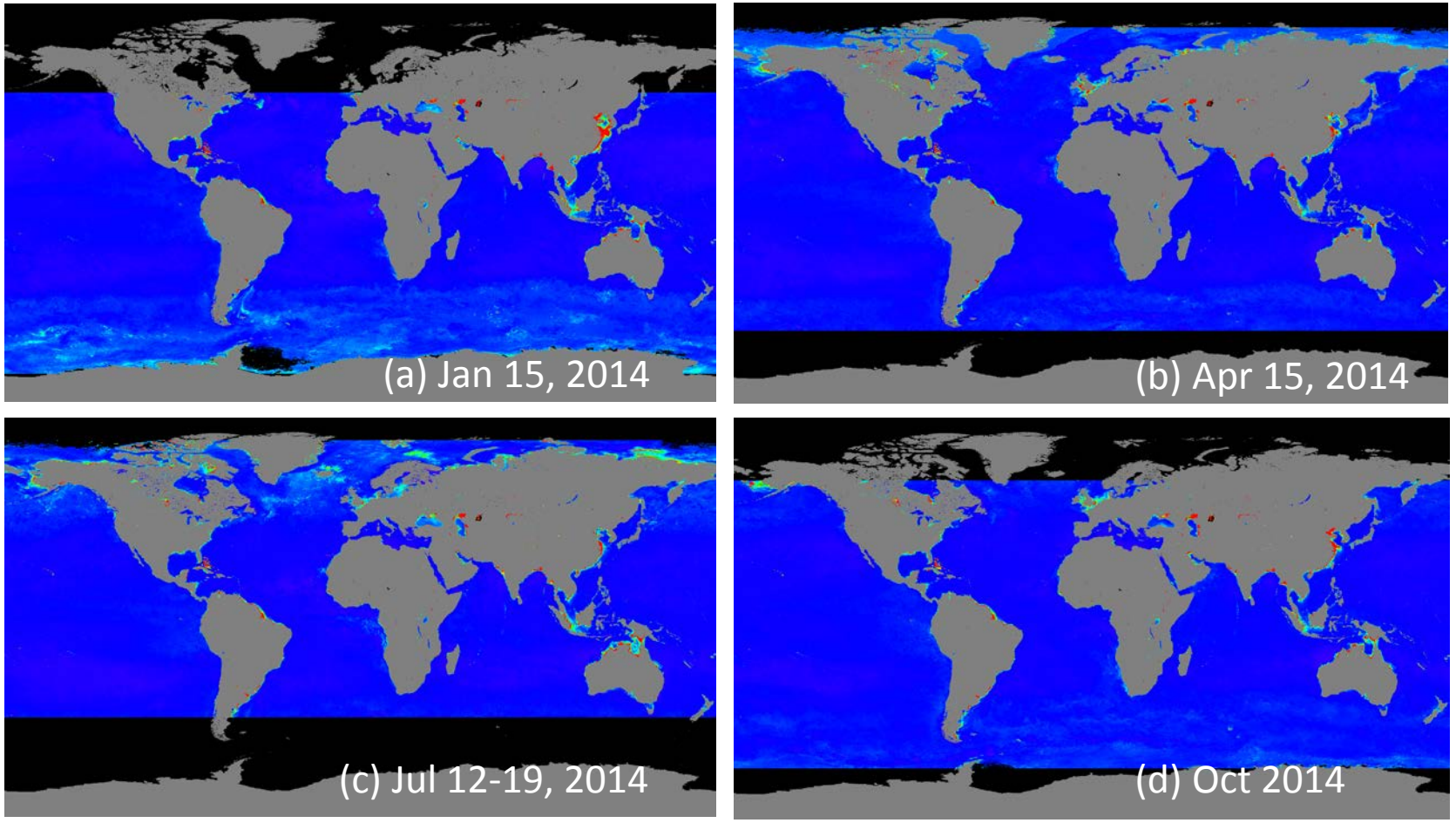
Reconstructed daily, 8-day, monthly $K_d(490)$ for (a) Jan. 15, (b) Apr. 15, (c) Jul. 12-19 8-day, and (d) Oct monthly in 2014.

Reconstruct Global $nL_w(443)$ Data Using DINEOF



Reconstructed daily, 8-day, monthly $nL_w(443)$ for (a) Jan. 15, (b) Apr. 15, (c) Jul. 12-19 8-day, and (d) Oct. monthly in 2014.

Reconstruct Global $nL_w(551)$ Data Using DINEOF



Reconstructed daily, 8-day, monthly $nL_w(551)$ for (a) Jan. 15, (b) Apr. 15, (c) Jul. 12-19 8-day, and (d) Oct. monthly in 2014.

Table 1. Recon/original Chl-a mean and STD for 8-day and monthly

Date	Mean	STD
V20140092014016_test_L3.nc	0.984342	0.152496
V20141052014112_test_L3.nc	0.983340	0.153924
V20141932014200_test_L3.nc	0.981758	0.157412
V20142812014288_test_L3.nc	0.981371	0.171772
V201401_test_L3.nc	0.988757	0.125213
V201404_test_L3.nc	0.990541	0.124521
V201407_test_L3.nc	0.981305	0.115728
V201410_test_L3.nc	0.979550	0.137193

Table 2. Recon/original K_d(490) mean and STD for 8-day and monthly

Date	Mean	STD
V20140092014016_test_L3.nc	0.991244	0.108033
V20141052014112_test_L3.nc	0.989462	0.110404
V20141932014200_test_L3.nc	0.990725	0.121529
V20142812014288_test_L3.nc	1.02204	0.125919
V201401_test_L3.nc	0.995703	0.104477
V201404_test_L3.nc	0.998743	0.0988738
V201407_test_L3.nc	0.995841	0.107785
V201410_test_L3.nc	1.00713	0.110283

Summary and Conclusions

- DINEOF is used to fill gap pixels in VIIRS global Level-3 data for Chl-a, $K_d(490)$ and $nL_w(\lambda)$.
- In the reconstructed daily Level-3 images, variations of both large-scale and small-scale dynamic features are captured.
- The reconstructed pixels are validated with 5% of good pixels that are artificially treated as mixing pixels.
- 8-day and monthly data are also reconstructed by binning the non-gap daily global Level-3 data, and results are quite reasonable.

NOAA CoastWatch/ OceanWatch Ocean Color Data Dissemination

Veronica P. Lance* and
Paul M. DiGiacomo
and the NOAA CoastWatch/OceanWatch Team

*Global Science & Technology, Inc.

2016 STAR/JPSS Annual Science Meeting
College Park, MD, 14-18 August 2017

STAR Center for Satellite Application and Research
National Environmental Satellite, Data, and Information Service (NESDIS)

NOAA CoastWatch/OceanWatch Team

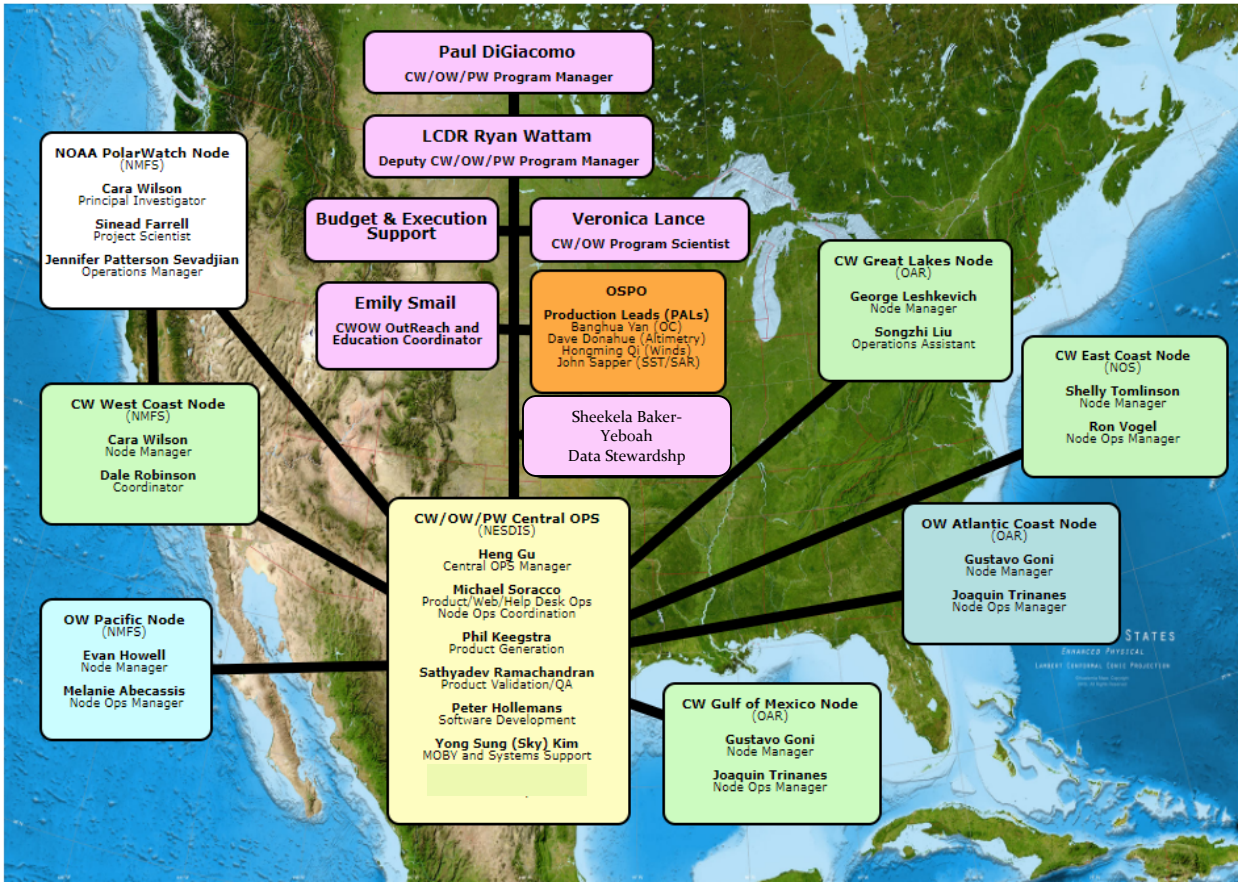
Paul DiGiacomo – Program Manager

Full Time "CW Central" Technical Team	With Support From
Heng Gu	Veronica Lance
Phil Keegstra	Emily Smail
Sathya Ramachandran	Sheekela Baker-Yeboah
Michael Soracco	Ryan Wattam

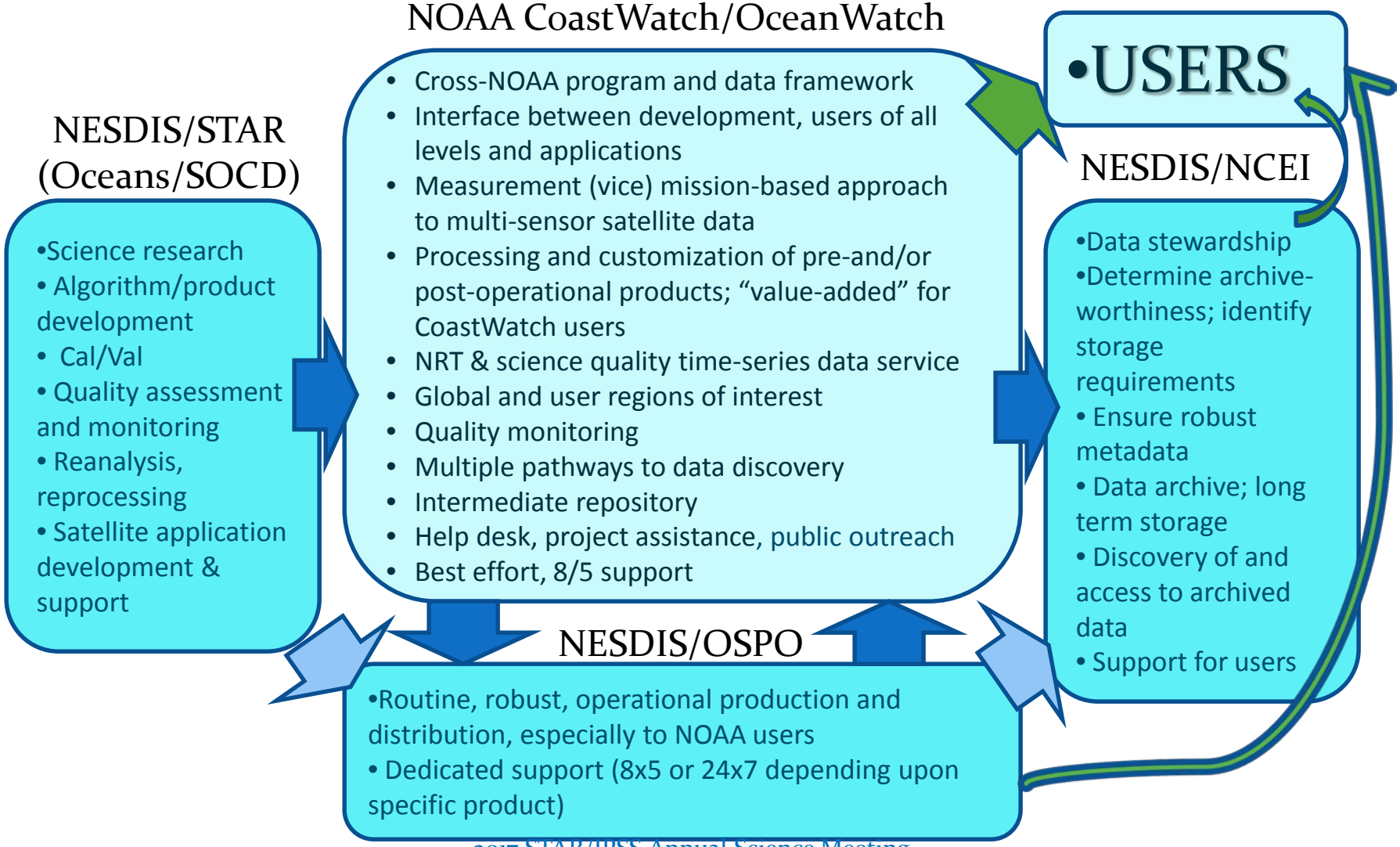
And PolarWatch
and 5 Regional Nodes

NOAA CoastWatch/OceanWatch/PolarWatch

CoastWatch Organization Chart

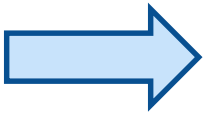


Role of NOAA CoastWatch/OceanWatch



Suomi NPP VIIRS OC Data Products

- Near Real Time (Days 1-14)
  - Global
  - Regional



Also: Now Operational at OSPO

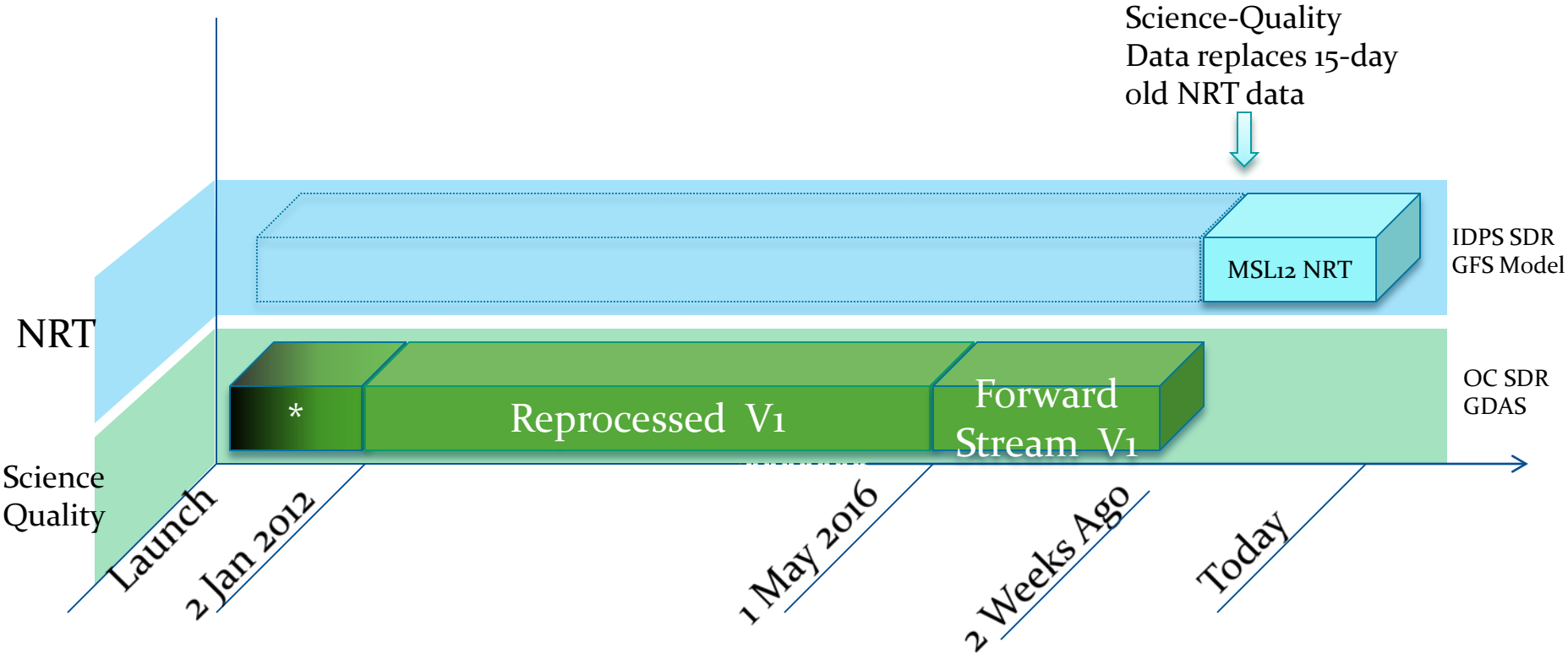
- Science Quality (Day 15 – 2 Jan 2012*)
  - Global
  - Regional

** Data from early mission (since launch Nov. 2011 to 2 Jan 2012) are available only upon special request and will be provided with a quality warning.*

NRT & Science Quality Data

Attribute	Near-Real Time	Delayed-Mode/Science-Quality
Latency:	Best effort, as soon as possible (~12-24h)	Best effort, on a 2-week delay
Processing System:	**MSL12** (v1.01; will transition to v1.2x)	**MSL12** (v1.2x)
SDR:	**IDPS Operational SDR**	**OC-improved SDR**
Ancillary Data:	Global Forecast System (GFS) Model	Science quality (assimilated; GDAS) from NCEP
Spatial Coverage:	May be gaps due to various issues	Complete global coverage
Processed by:	OSPO (operational)	NOAA/STAR
Distributed by:	CoastWatch , OSPO	CoastWatch, NCEI
Archive Plans:	Yes, from OSPO to NCEI	Yes, from CoastWatch to NCEI
Full Mission Reprocessing:	No	Yes, every ~2-3 years or as needed

Example "Snapshot"



*Early mission data are not publically distributed due to quality issues. They can be specially requested but will come with a quality warning.

L2 & L3 Global Products

- Standard:
  - Chlorophyll-a
  - $K_d(490)$
  - $K_d(\mathrm{PAR})$
  - nL_w 5 M-Bands
    - 412
    - 445
    - 488
    - 555
    - 672
  - $nL_w(638)$ I-Band
  - QA Score
  - L2_flags
  - Latitude
  - Longitude

- Experimental:
  - IOPs
  - PAR

Future inclusion as released by MECB

L2 & L3 Sector and Regional Products

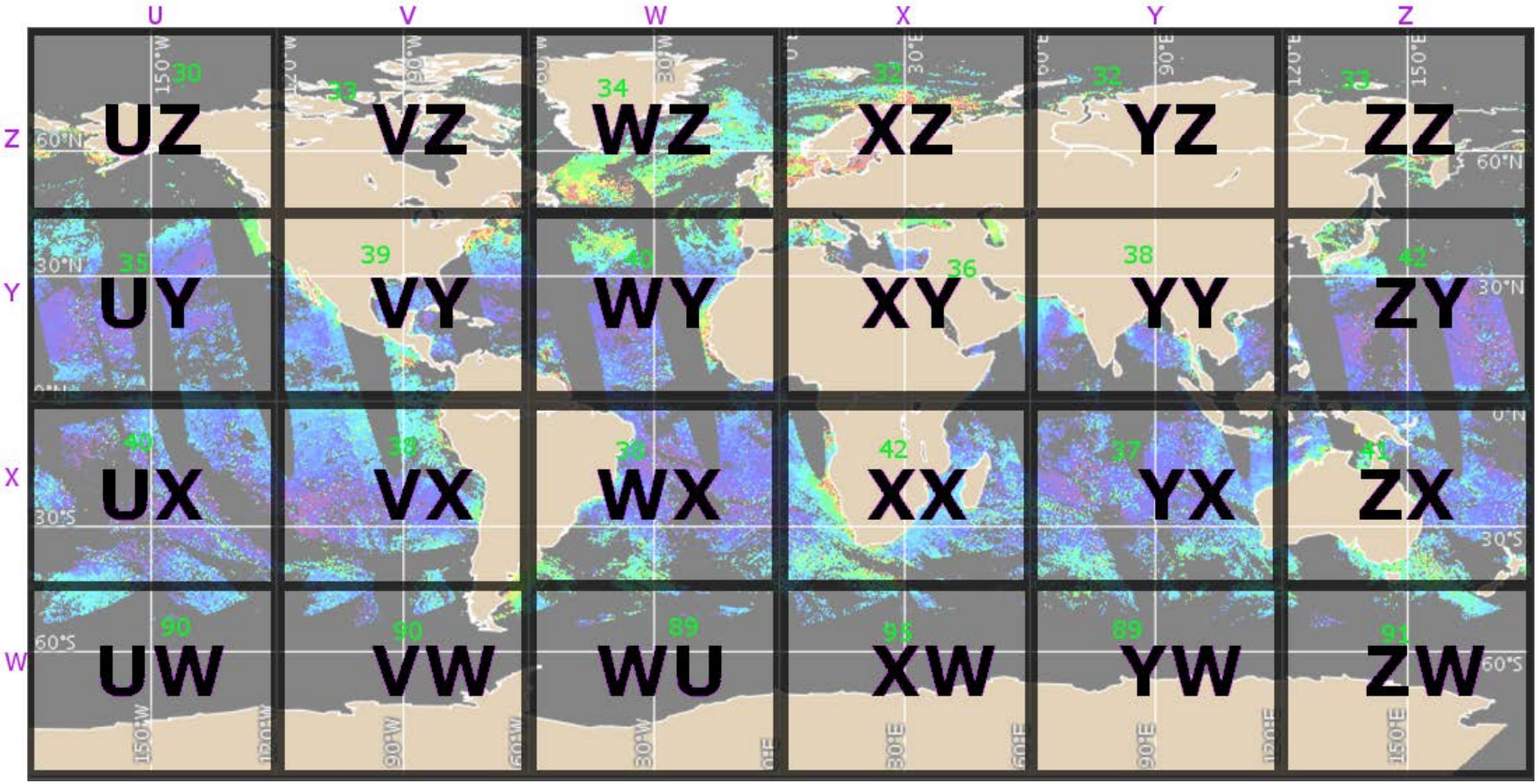
- Standard:
  - Chlorophyll-a
  - $K_d(490)$
  - $K_d(\mathrm{PAR})$
  - nL_w 5 M-Bands
    - 412
    - 445
    - 488
    - 555
    - 672
  - $nL_w(638)$ I-Band
  - QA Score
  - L2_flags
  - Latitude
  - Longitude
  - Edgemask

- Experimental:
  - IOPs
  - PAR

Future inclusion as released by MECB

- User Driven ("Customized" routine production; considered upon request):
  - HAB anomaly product
  - R_{rs}
  - Special projections
  - Etc.

L3 Global 750m Sectors



CW Distribution of NRT

Product Description	Processing Level	Nominal Spatial Resolution	Chl-a	nLws	KdPAR	Kd490	Rrs (672)	Chlorophyll Fronts	True Color
Daily granule global swath	L2	750 m	X	X	X	X	X		X
Daily merged mapped CW regions*	L3	750 m	X		X	X	X		X
Daily merged global single file	L3	4 km	X	X	X	X			
Daily merged global sectorized**	L3	750 m	X	X	X	X		X (3 sectors: UY, VY, WY)	
7-day merged global single file	L3	4 km	X	X	X	X			
7-day merged global sectorized**	L3	750 m	X	X	X	X			
True monthly merged global single file	L3	4 km	X	X	X	X			
True monthly merged global sectorized**	L3	750 m	X	X	X	X			
61 day merged for CW regions*	L3	750 m	X				X		
Anomaly for CW regions*	L3	750 m	X				X		
Daily granule Mediterranean	L1b, L2	750 m	X	X	X	X			
Daily merged mapped Mediterranean	L3	750 m	X		X	X			
Daily merged mapped Australia	L3	750 m	X		X	X			

CW Distribution of Science Quality

Product Description	Processing Level	Nominal Spatial Resolution	Chl-*a*	*nLws*	K_d(PAR)	K_d(490)	QA Score
Daily granule global swath @750 m	L2	750 m	X	X	X	X	X
Daily merged global sectorized *	L3	750 m	in progress at CW	in progress at CW	in progress at CW	in progress at CW	in progress at CW
7-day merged global sectorized *	L3	750 m	in progress at CW	in progress at CW	in progress at CW	in progress at CW	in progress at CW
True monthly merged global sectorized *	L3	750 m	in progress at CW	in progress at CW	in progress at CW	in progress at CW	in progress at CW
Daily merged global single file	L3	4 km	X	X	X	X	X
7-day merged global single file	L3	4 km	X	X	X	X	X
Monthly merged global single file	L3	4 km	X	X	X	X	X

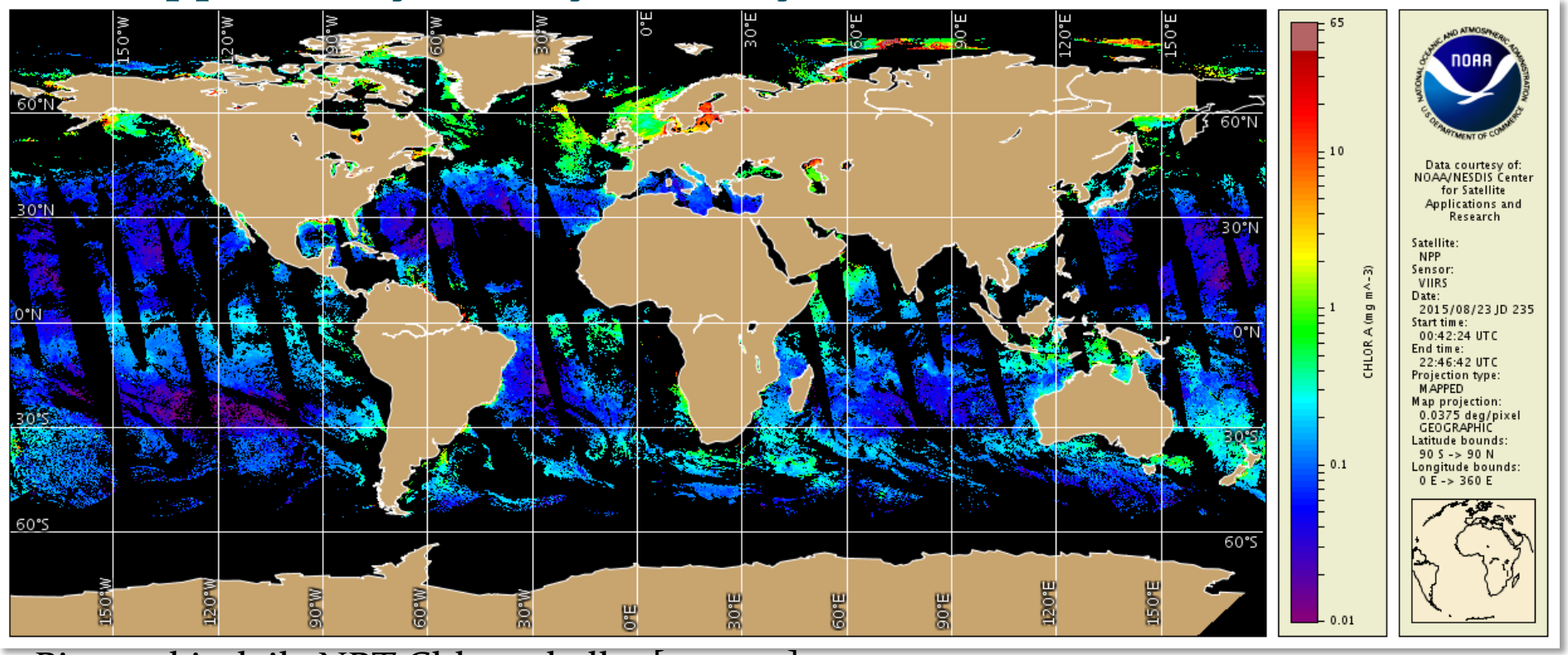
Data Formats

- Global and Sector:
  - NetCDF v4CF
  - GeoTIFF & PNG

- Tailored and CONUS Regional:
  - NetCDF v4 CF
  - GeoTIFF & PNG
  - HDF (v4 with CoastWatch metadata; to be phased out)

L3 NRT Global 4km

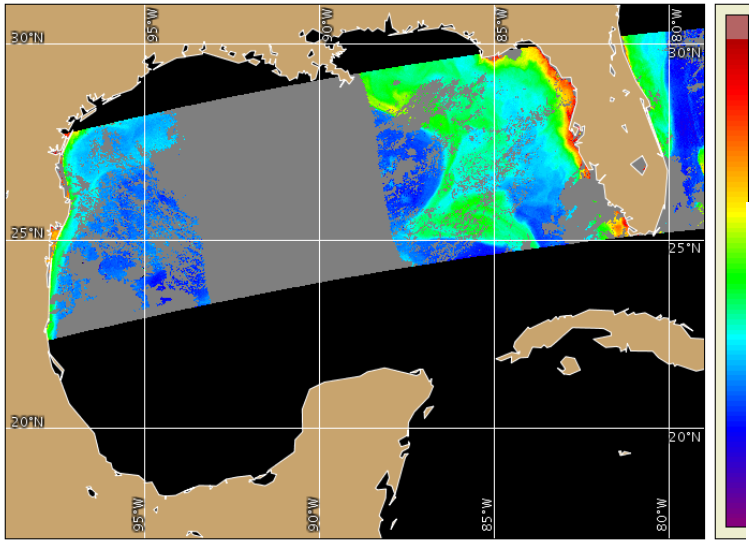
(mapped, daily, weekly monthly)



Pictured is daily NRT Chlorophyll-a [mg m^{-3}];

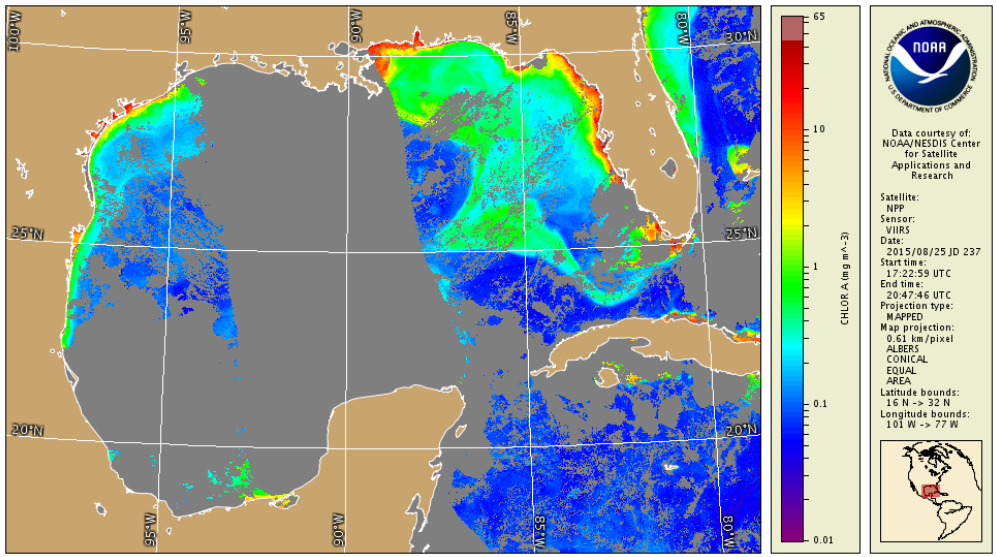
NRT Regional

- "CONUS" 750m regions: Hawaii, West Coast, Great Lakes, Northeast, Southeast, Gulf of Mexico, Caribbean



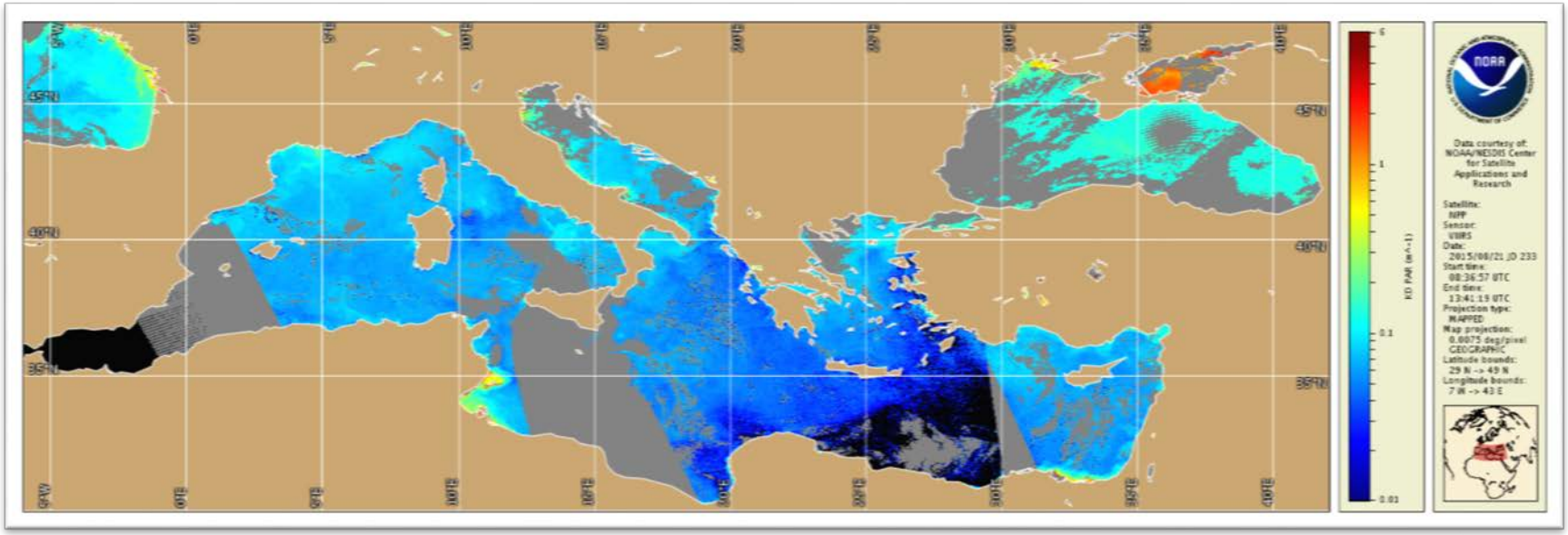
Granule

Daily Merge for Caribbean Region



International Partners (1)

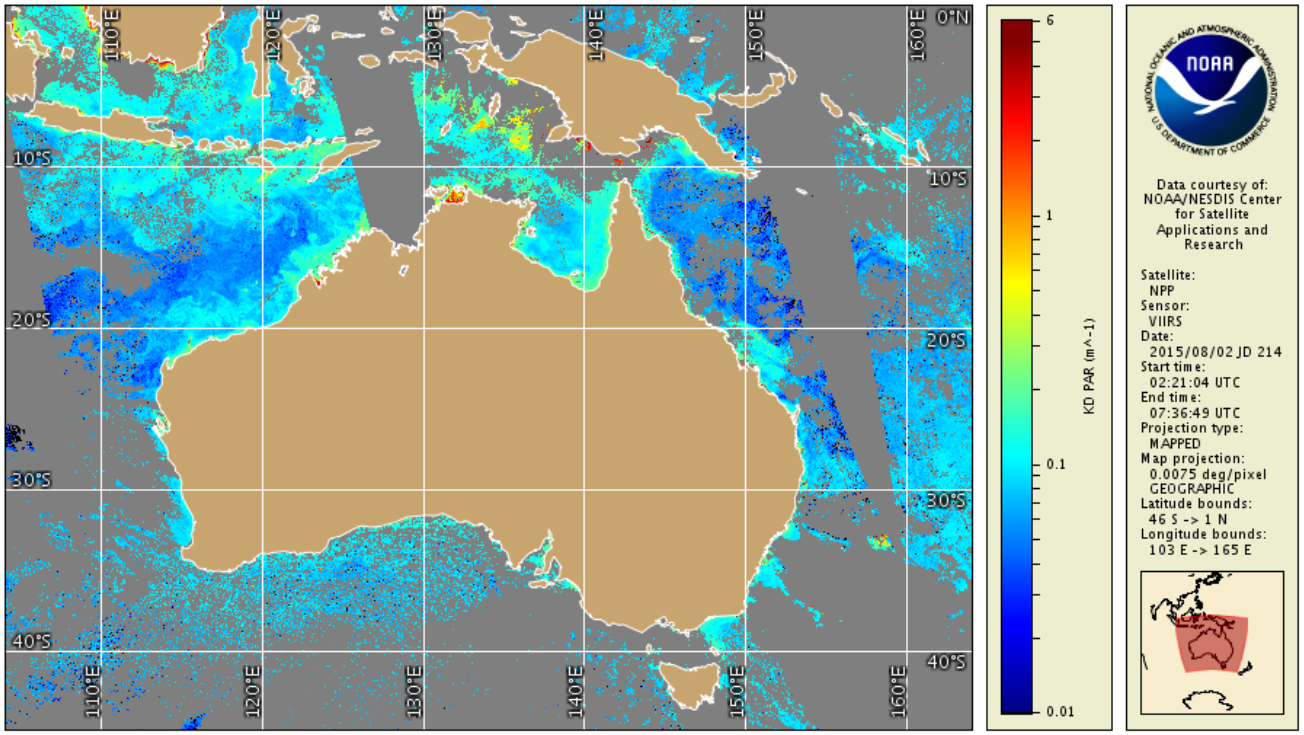
- EUMETSAT
  - Processing and staging of L2 750m Mediterranean datasets
  - EUMETcast (Copernicus Service) broadcasts VIIRS data to EU



Shown: L3 Daily merge, mapped, k_dPAR [m^{-1}]

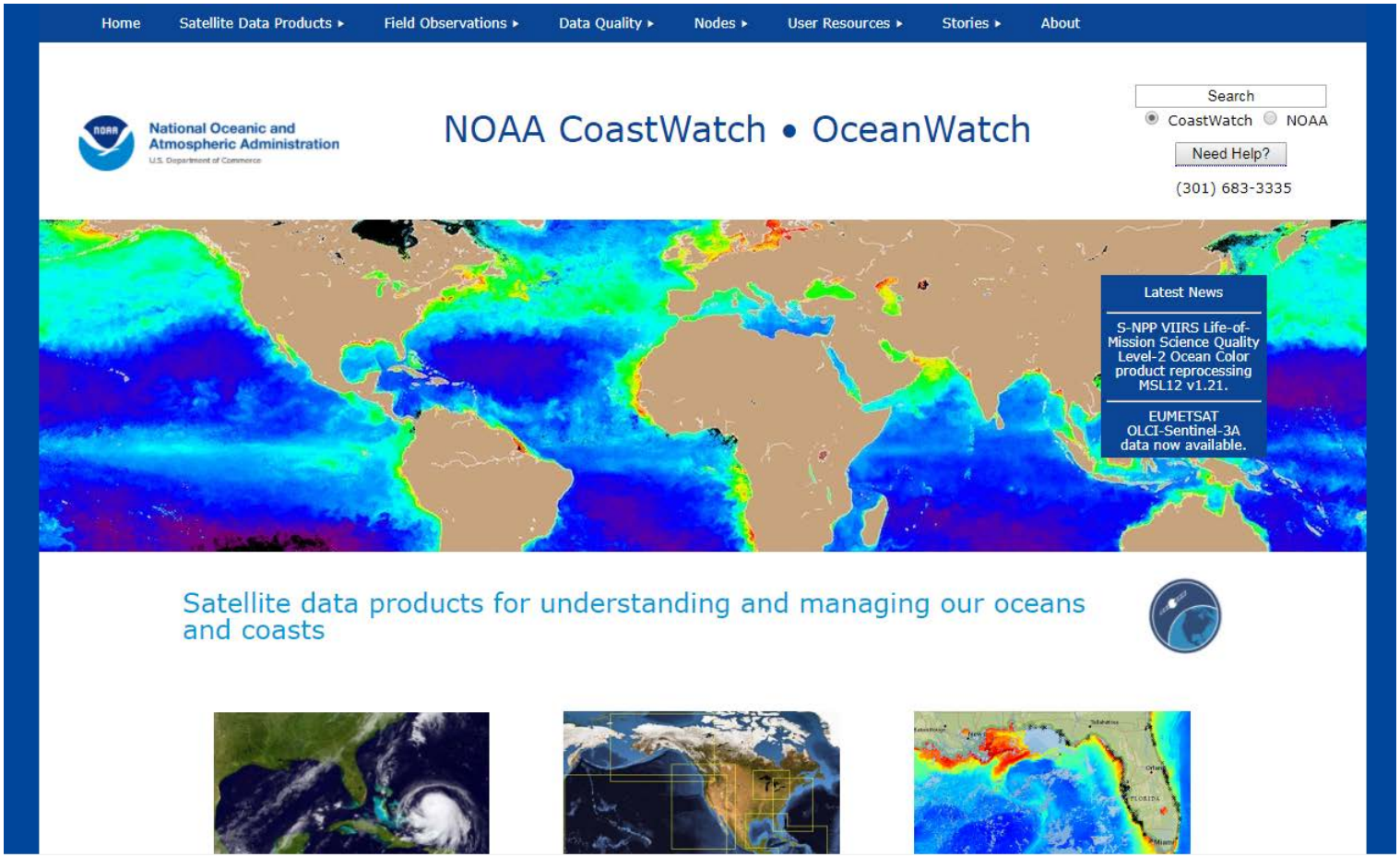
International Partners (2)

- CSIRO
  - Processing and staging of L3 Australia 750m datasets

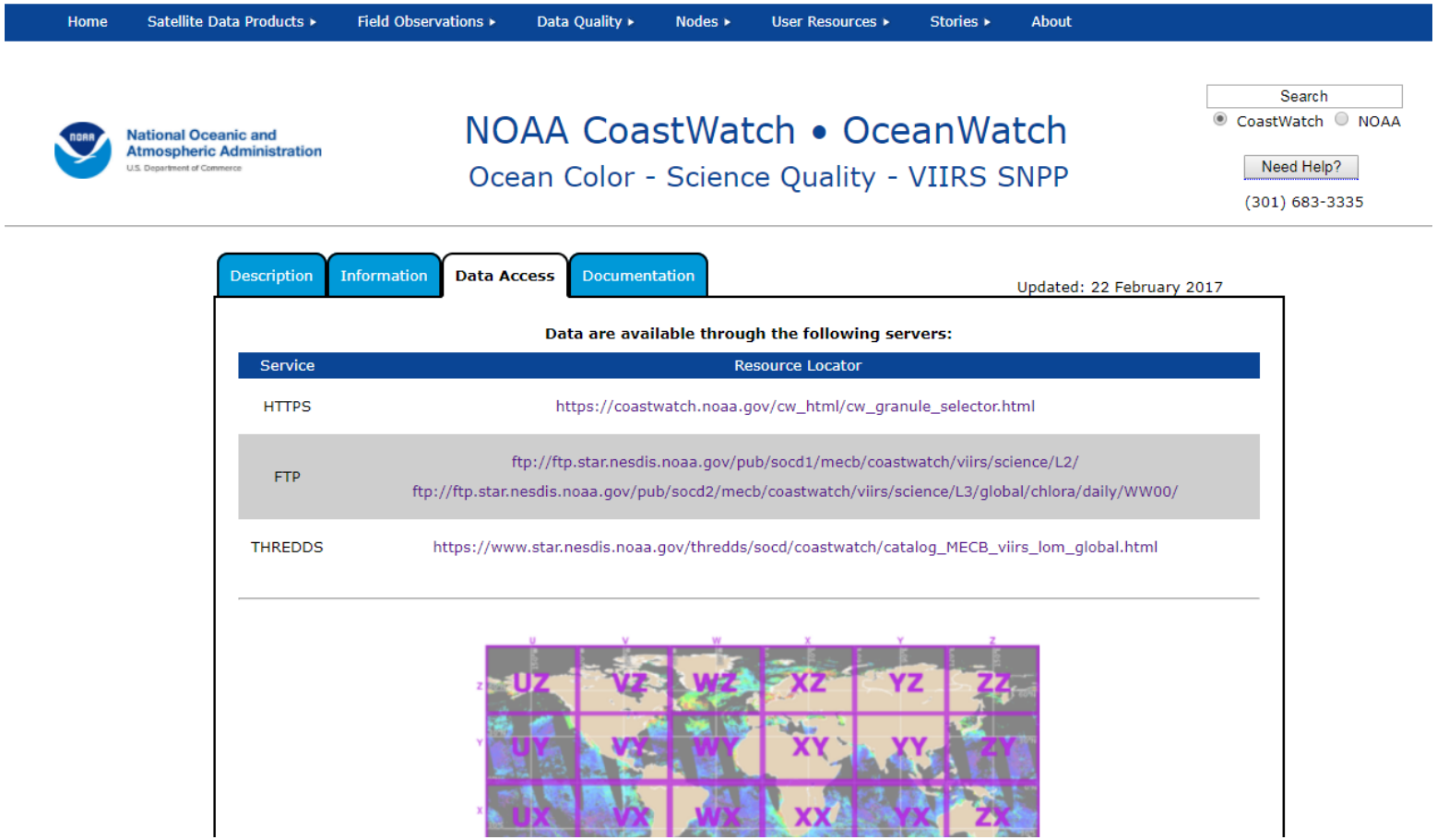


Daily Merge, mapped, k_dPAR [m^{-1}]

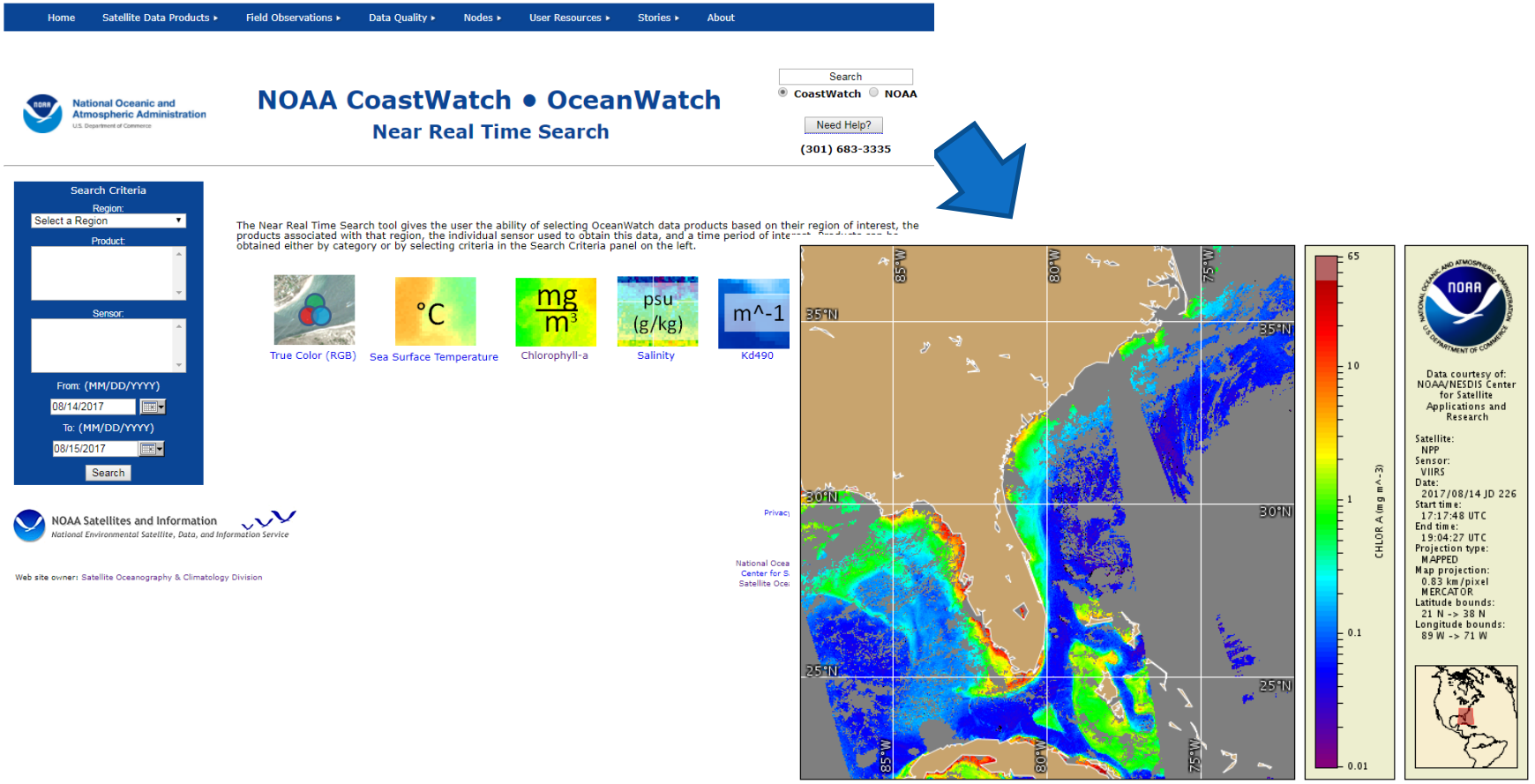
Website Revamp v.1.2 in Progress



OC Product Pages

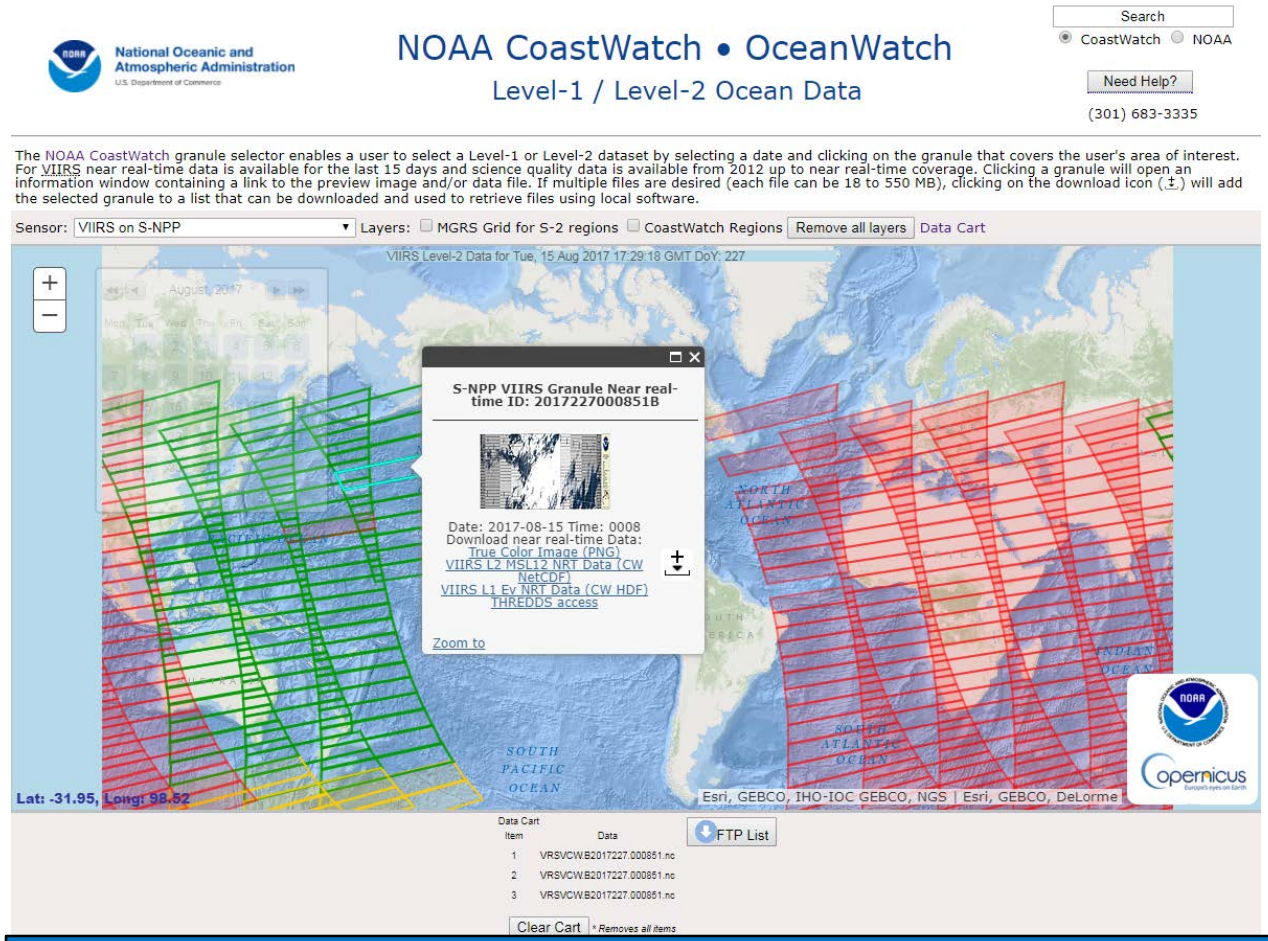


NRT Search



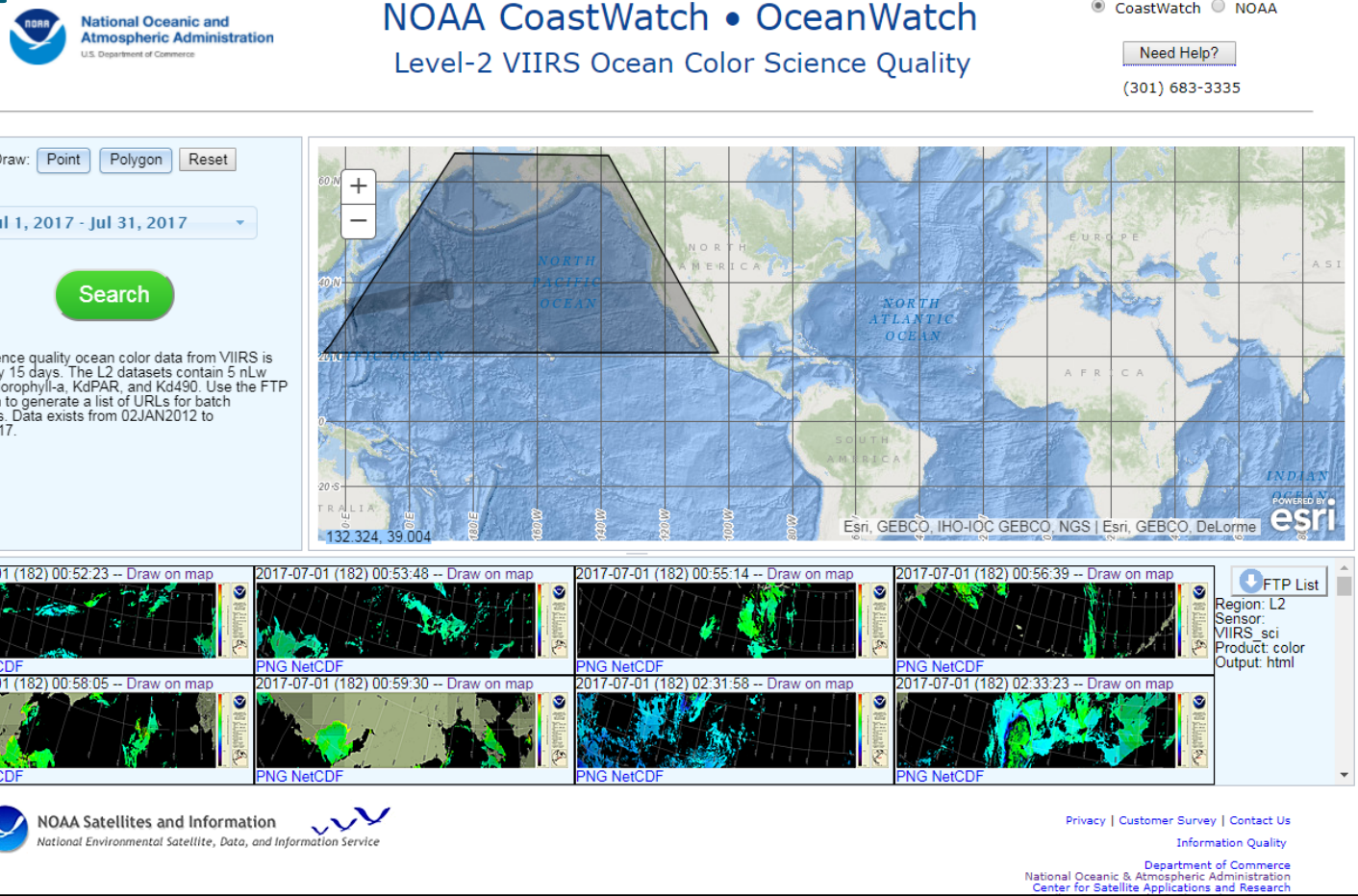
https://coastwatch.noaa.gov/cw_html/NearRealTimeSearch.html

L2 Granule Selector



https://coastwatch.noaa.gov/cwn/cw_granule_selector.html

L2 Spatial Search Tool



https://coastwatch.noaa.gov/cw_html/cw_polygon_search.html#searchbox

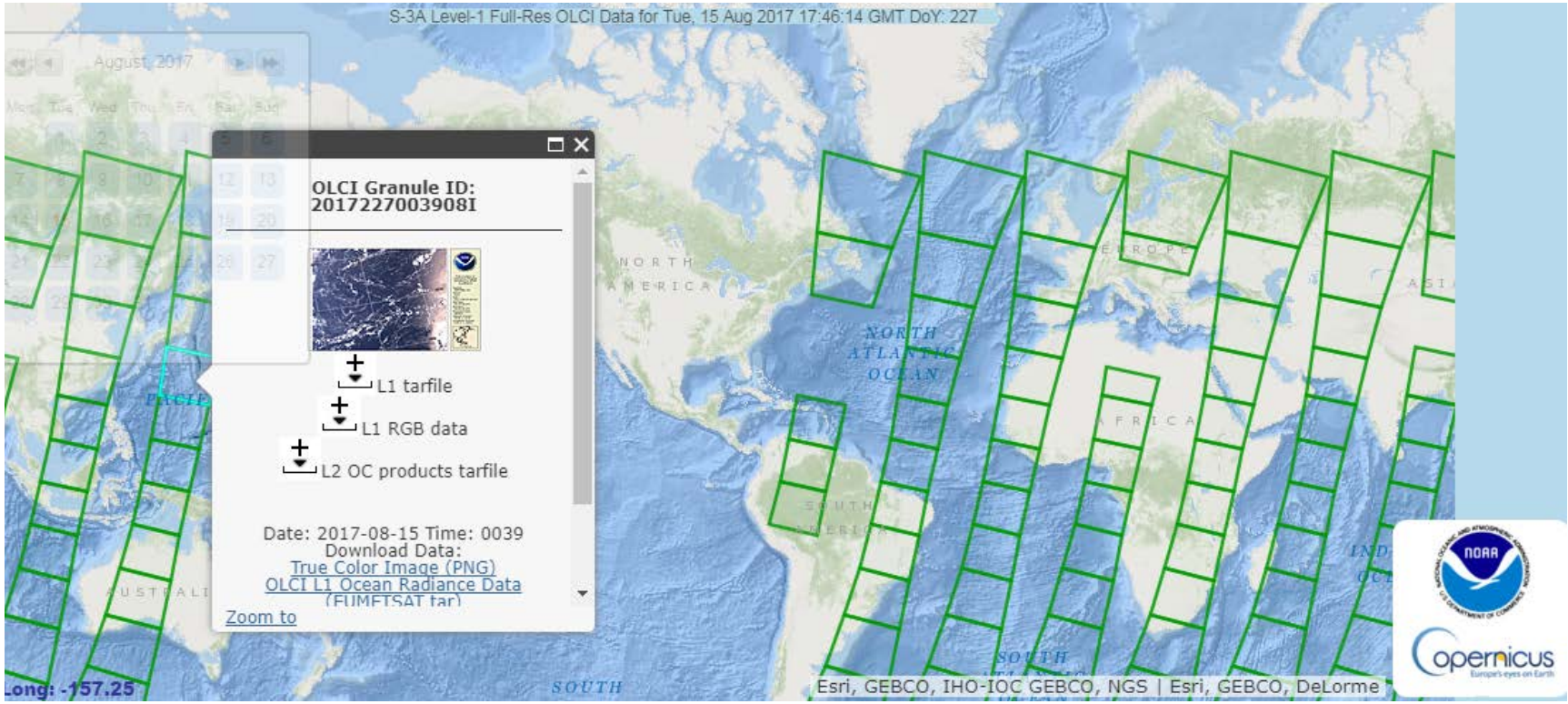
Data Stewardship and Long-Term Archive by NCEI

- NOAA CoastWatch/OceanWatch is delivering MSL12 full mission science quality data (L2 and L3) for data stewardship and long-term archiving by NCEI.
- Data will be stored at CLASS but easily accessible via CoastWatch and through NCEI spinning disk
- Spinning disk access page in progress, ***waiting on me to edit the content description.***

Sentinel-3A OLCI

- A Cooperative Arrangement between the United States and the European Commission and technical arrangements between NOAA and EUMETSAT (and NOAA and ESA for S1 and S2) are all complete.
- NOAA is primary outlet in US for Sentinel 3 marine data.
- EUMETSAT data transfer via terrestrial multicast to NOAA/STAR is now routine. L1 and L2 marine data products are now available through CW.
- NOAA CoastWatch/OceanWatch provides near real-time access to global OLCI (L1b and L2 full and reduced resolution)
- SLSTR data products from EUMETSAT and SRAL data are coming into STAR and will be redistributed through CoastWatch.
- OLCI data complements existing JPSS sensors:
  - 300m spatial resolution
  - Spectral bands meeting NOAA NOS HAB requirements
  - Morning vs. afternoon orbits
  - Relieves single point-of-failure for HAB forecasting

Sentinel-3A OLCI



Summary (1)

Both NRT and Science Quality VIIRS-SNPP Ocean Color data are available through NOAA CoastWatch/OceanWatch.

Science Quality

L2 global, granules:

FTP:

ftp://ftp.star.nesdis.noaa.gov/pub/socd1/mecb/coastwatch/viirs/science/L2/

THREDDS:

https://www.star.nesdis.noaa.gov/thredds/catalog/swathNPPVIIRSSCIENCEL2WW00/catalog.html

Or, you can interactively select and download data (or get your file list for automated commands) using the Granule Selector Tool here:

https://coastwatch.noaa.gov/cwn/cw_granule_selector.html

L3 global 4 km mapped:

FTP:

ftp://ftp.star.nesdis.noaa.gov/pub/socd1/mecb/coastwatch/viirs/science/L3/global/

Summary (2)

Both NRT and Science Quality VIIRS-SNPP Ocean Color data are available through NOAA CoastWatch/OceanWatch.

Near Real Time

THREDDS OC NRT main page:

https://www.star.nesdis.noaa.gov/thredds/socd/coastwatch/catalog_coastwatch_viirs_global.html

Includes: L2 global granules (swath); L3 global 4km mapped, daily, weekly, monthly merged

Or, you can interactively select and download data (or get your file list for automated commands) using the Granule Selector Tool here:

https://coastwatch.noaa.gov/cwn/cw_granule_selector.html

Thank You

Web Site: CoastWatch.NOAA.gov

Help Desk:

Coastwatch.info@NOAA.gov

Me: VeronicaLance@NOAA.gov

"Current Status of MOBY Data Products"

UNIVERSITY OF MIAMI

Kenneth Voss, Physics Dept., Univ of Miami

Co-Authors: Mark Yarbrough (MLML), Carol Johnson (NIST), Stephanie Flora (MLML), Mike Feinholz (MLML), Art Gleason (UM), Howard Gordon (UM), and Terry Houlihan (MLML)

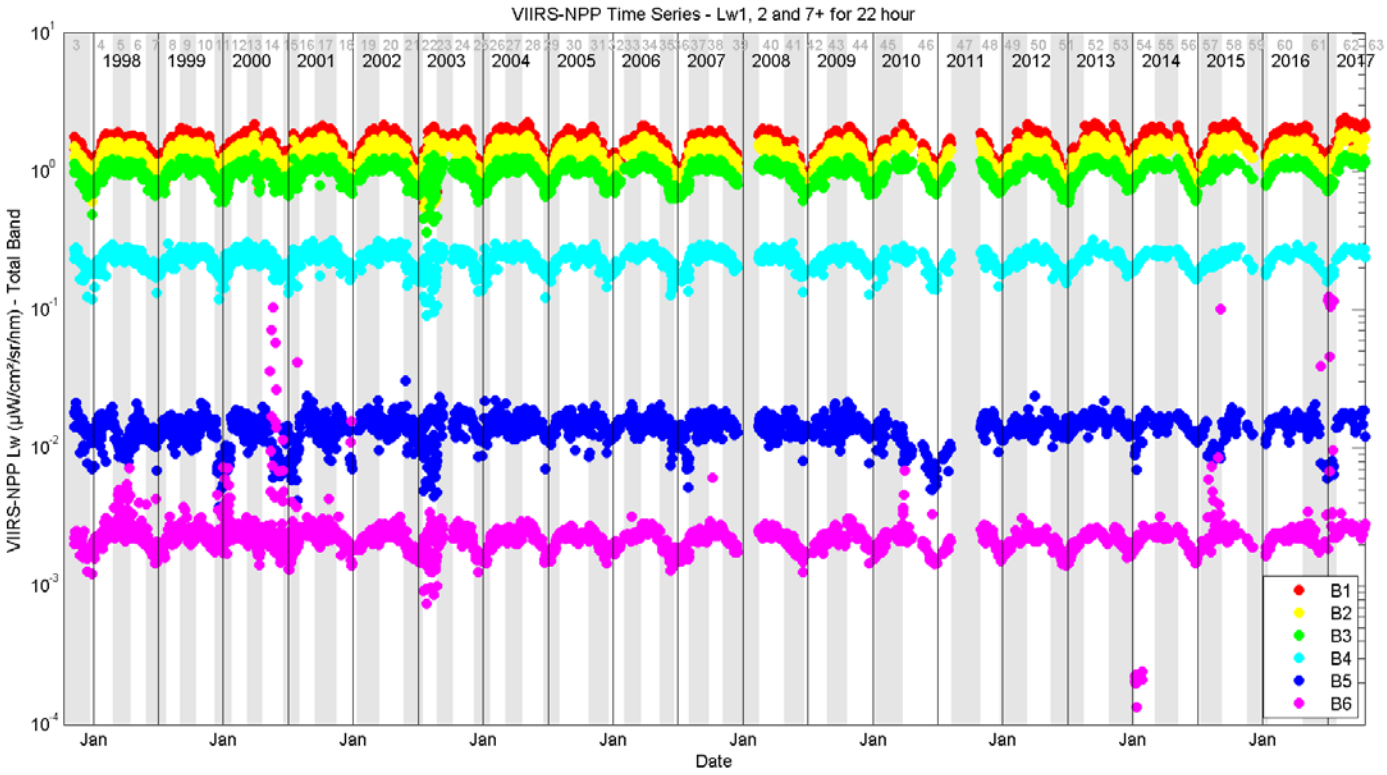
8/17, STAR JPSS 2017 annual meeting, College Park, Md.

1) Brief statement on current status of MOBY Operation and Refresh

2) Explanation of M261 post calibrated data posting

3) Description of corrections we are working on implementing in the data stream.

Currently have a 20 yr. time series of vicarious calibration data at the MOBY site thanks to NASA, NOAA, Dennis Clark, and the rest of the MOBY team (many of whom have been in the project since the beginning).



Current status

- Deployment M263 started approximately 8/2.
- Currently working through controller issues, but the data is looking good. Getting 22 hr and 00 hr(or 23hr) files each day, but not 20 hr file, working on understanding why.
- We are on our third deployment of the new Blue spectrometer system. We are learning and testing for the optimal acquisition and data reduction procedures for this new system.

As might be recalled, M261 was a deployment that had several issues. At the beginning the pre-calibration for the mid arm was suspect, so we did not use the midarm measurement and only produced and posted the product Lw2 which uses the top arm and the bottom arm.

Mid deployment the top arm was broken off, and we were then forced to make a new product which used the lower arm measurement, and an empirical, seasonal KL to propagate this to the surface. This product was called Lw14

With the post-calibrations we found that we could recover the midarm measurement after the arm had been damaged, but this did not propagate backwards beyond this point (other calibrations must have been effected when the collision that broke the arm occurred).

Taking all of this into account, we have replaced the data on the data directory with the post calibrated data.

This post calibrated data has two “epochs”:
1) the time period before the top arm was broken off uses the top and bottom arm, with the precalibrations to produce Lw2 and Lwn2. (and associated Lw22 and Lwn22 for wavelengths greater than 575 nm).

2) the time period after the top arm was broken off will use post calibrated mid arm and lower arm data to produce the Lw7 and Lwn7 product (and associated Lw27 and Lwn27 for red wavelengths).

IMPORTANT: Note that with the post cal, we have taken down data the Lw14 product that was produced during the deployment to give “real time” data. Also, now that we have midarm and lower arm data, thus a real KL measurement to evaluate, some days have changed their quality designation (good, bad or questionable).

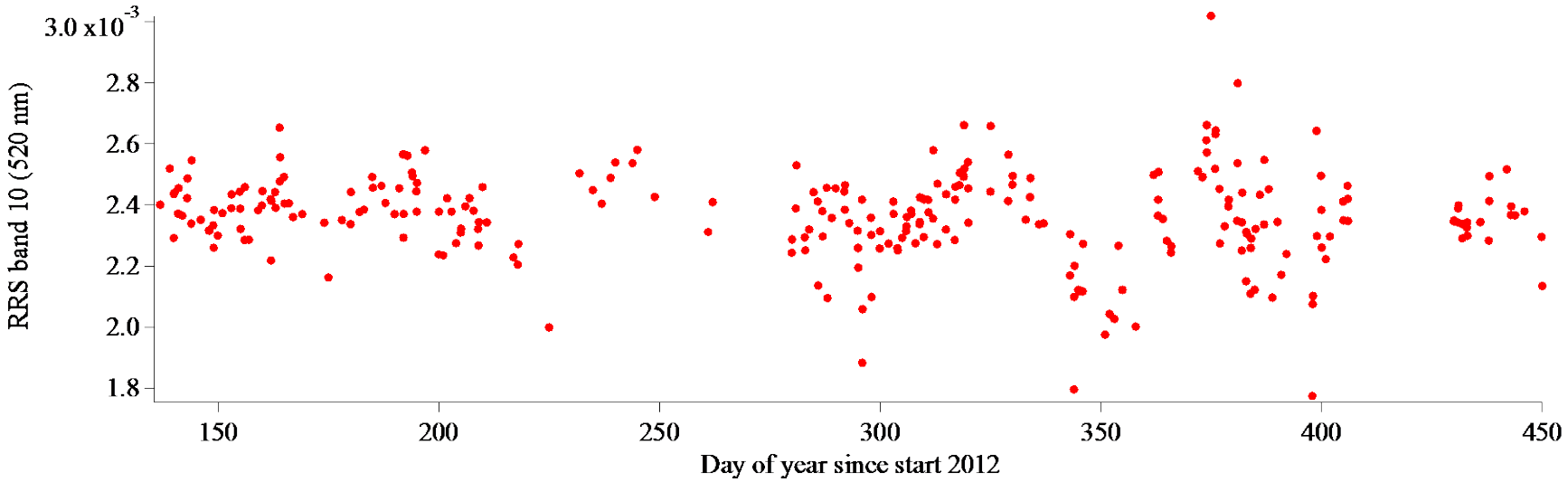
We are working on ways to improve the accuracy of the MOBY data product, along with doing a better assessment of the environmental induced uncertainties in the data products.

Some of the factors, that we can model, include tilting of the Es collector, the BRDF effect and tilting the radiance collector, tilt of the buoy changing the Lu measurement depth, and possibly the biggest, instrument self-shadowing.

We can evaluate each of these individually and look on the effect on the data. To investigate an apparent optical property, rather than a radiometric property, we will look at the remote sensing reflectance, RRS = Lw/Es during two deployments in 2012/2013.
I will select RRS 520 nm, as it should be fairly stable.

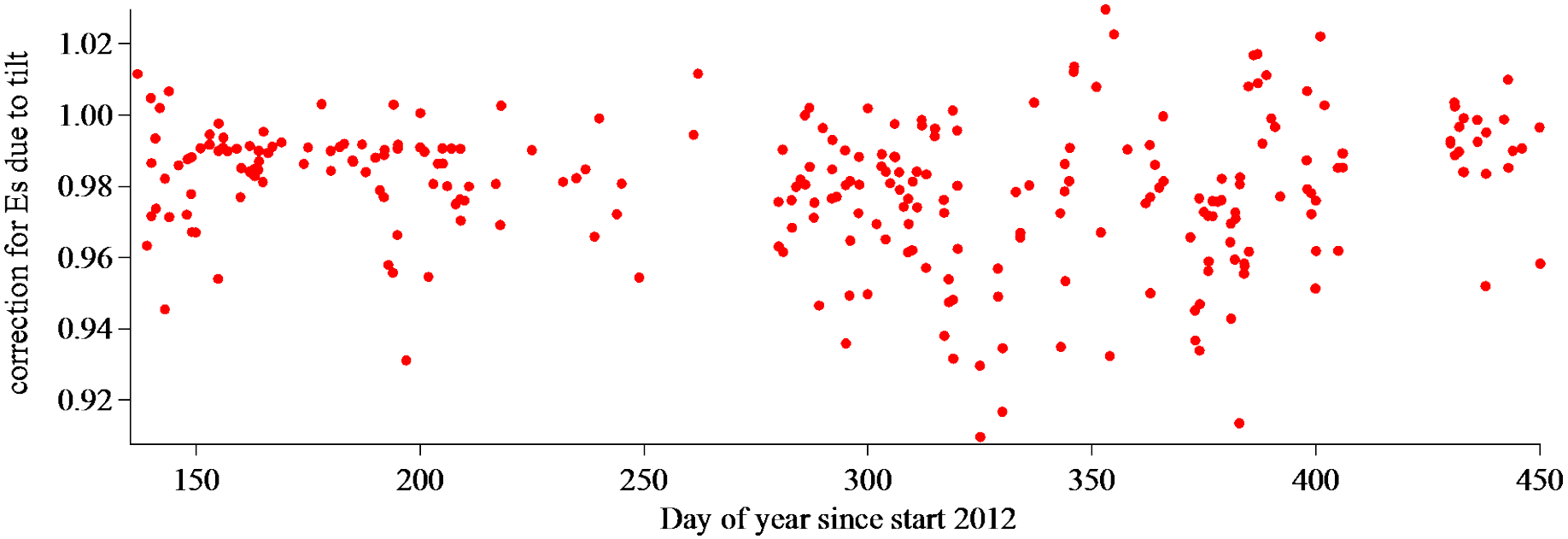


RRS(520 nm) for the two deployments in 2012-2013

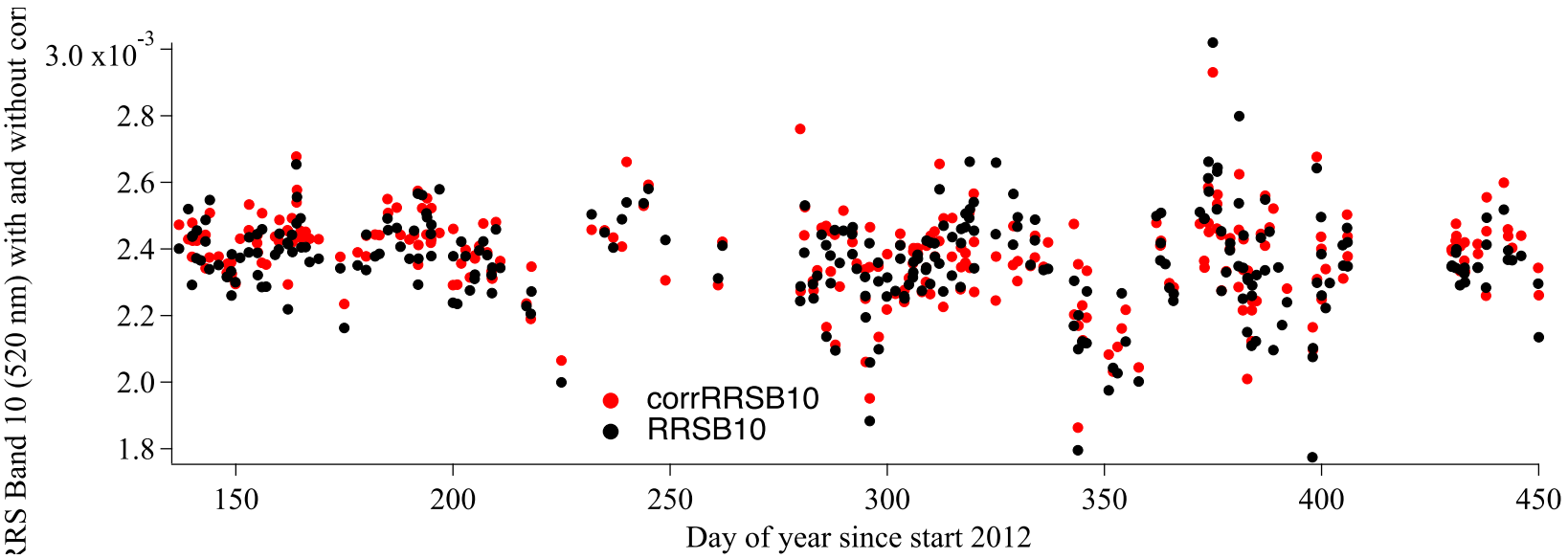


Mean is 0.0024, while the COV is 6%

The correction for irradiance collector tilt (and actual cosine response) is shown below. As can be seen, this correction (for the most part less than 1) can be a significant effect, although it is also generally less than 2%.

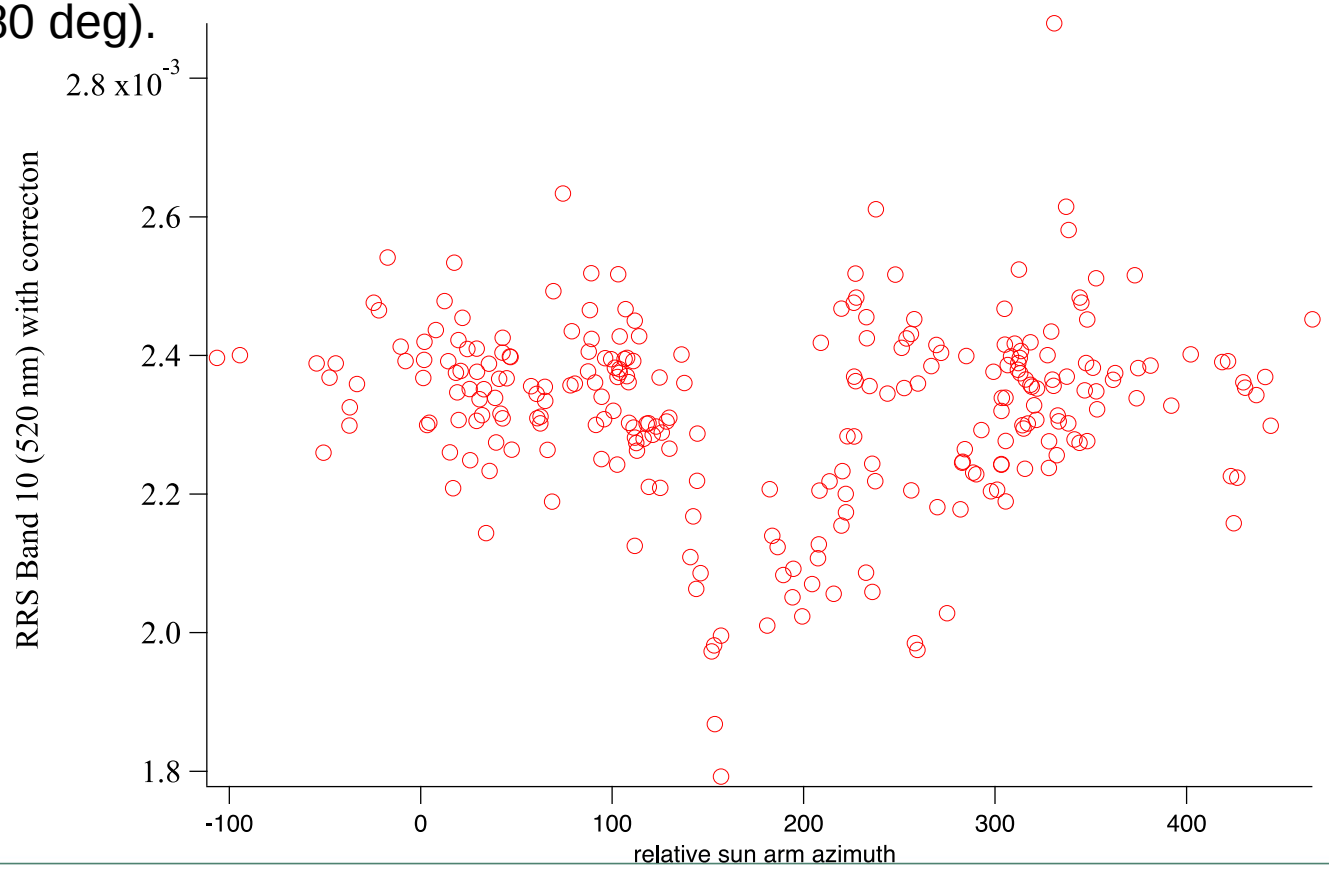


Other corrections include accounting for solar zenith angle, BRDF effects, and small arm depth corrections. These are typically less than 1% effects. So the data with and without these corrections looks like:



In this, the mean is slightly lower (<2% change) and COV is slightly better (5.4% vs. 6/2%).

So far this is without a shadowing correction. The graph below shows the corrected RRS vs. relative sun-arm azimuth. 180 degrees is when the arm and buoy are lined up such that the sun is on the opposite side of the buoy from the arm, maximum shading. As can be seen the lowest points are occurring when the buoy is oriented in this manner, hence these lowest points, while not many in number, need the shadowing correction which we are still working on (about 10% effect at 180 deg).



Time series is on-going, now 20 years long.

New deployment has just started, with 3rd deployment of blue spectrograph

M261 post calibrated data has been posted to the Coastwatch site

We are working on various modeling efforts which could help with both improving the data set and documenting the measurement uncertainty

STAR JPSS 2017
Annual Science Team Meeting

VIIRS Ocean Color Breakout
Wednesday , 16 August 2017

Optical Measurements in Support of JPSS Cal/Val

Michael Ondrusek, Eric Stengel and Charle Kovach
Bob Arnone, Zhongping Lee, Eric Stengel, Sherwin Ladner, Scott Freeman, Wesley Goode, Chuanmin Hu, David English, Jianwei Wei, Junfang Lin, Alex Gilerson, Sam Ahmed, Ahmed El-Habashi, Robert Foster, Nick Tufillaro, Curt Davis, Matteo Ottaviani, Michael Twardowski, Carlos Carrizo, Veronica Lance, Menghua Wang.

Location	Season	Year	Stations	Status	To Menghua	Seabass Format	
Ches. Bay GEOCAPE	July	2012	57	Processed	No	Yes	NASA GEOCAPE
Chesapeake Bay 2012							
VIIRS Launch							
Chesapeake Bay 2012	Dec	2011	2	Processed	Yes	No	First VIIRS validation VIIRS data not saved.
South Florida	Mar	2012	17	Processed	Yes	No	First good validation, lots of matchups.
Oahu, HI	September	2012	21	Processed	Yes	Yes	Many good matchups
Chesapeake Bay 2013	All Year	2013	37	Processed	Yes	No	Many good matchups and Red Tide and Mabel overflight
CUNY Ches. Bay Exp.	Aug	2013	42	Processed	Yes	No	Some matchups, Good closure experiment
GOM GEOCAPE	September	2013	67	Processed	Yes	Yes	Many good matchups in lots of conditions
Chesapeake Bay 2014	All Year	2014	27	Processed	Yes	Yes	Many good matchups and Red Tide and JOEYS
Puerto Rico	May	2014	15	Processed	Yes	Yes	Many good matchups
Hawaii/MOBY	May	2014	12	Processed	Yes	Yes	Good matchups with VIIRS and MOBY
VIIRS Cal/Val	Nov	2014	23	Processed	Yes	in process	Many good matchups
Chesapeake Bay 2015	All Year	2015	7	Processed	Yes	Yes	Many good matchups
Puerto Rico	Mar	2015	15	Processed	Yes	Yes	Many good matchups
East Coast Ocean Acidification	Jun/July	2015	74	Processed	Yes	Yes	Many good matchups
VIIRS Cal/Val	Dec	2015	27	Processed	Yes	Yes	Many good matchups
Chesapeake Bay 2016	All Year	2016	6+	Processed	No	No	Landsat validation
KORUS OC	May/June	2016	35	Processed	Yes	Yes	Many good matchups
West Coast Ocean Acidification	May/June	2016	35	Processed	Yes	Yes	lots of clouds some good matches
Fiji to Australia	Jun/July	2016	24	Processed	Yes	Yes	Several Matchups
CORAL PRISM	Oct	2016	37	Processed	No	Yes	Hurricane Matthew
VIIRS Cal/Val	Oct	2016	12	Processed	Yes	No	Several Matchups
P18 South Pacific	Jan/Feb	2017	45	Processed	No	Yes	includes south pacific gyre low chl H2O
JOEYS	March	2017	12	No	No	No	
Chesapeake Bay 2017	All Year	2017	17	No	No	No	
Total since VIIRS			**603**				

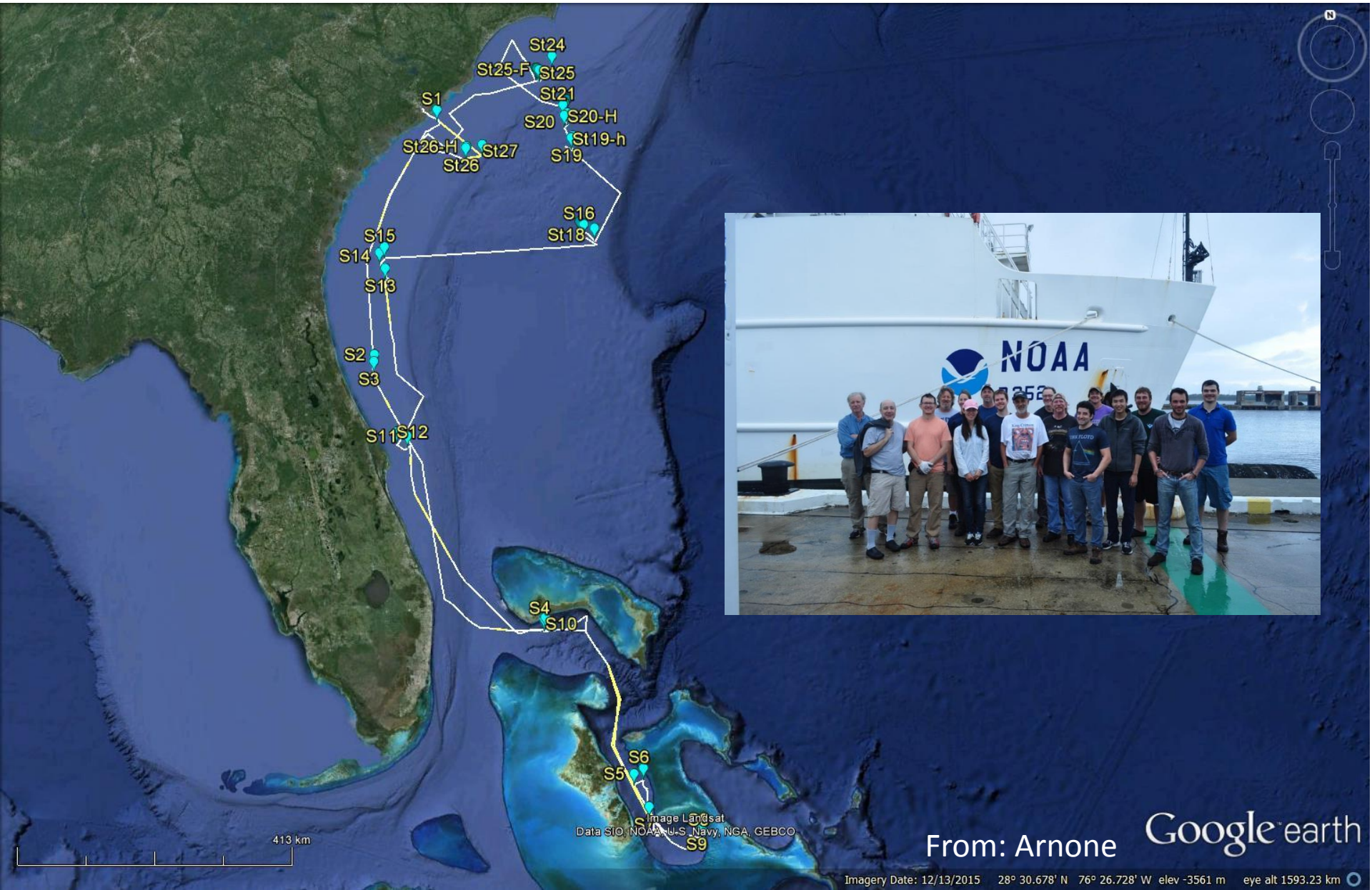
Primary Objectives:

- Provide in situ ocean color data to be used for calibration and validation of the JPSS Cal/Val effort.
- Define uncertainties in validation data collection.
- Outline best protocols to address validation and collection issues.

November 2014 Cal/Val Cruise

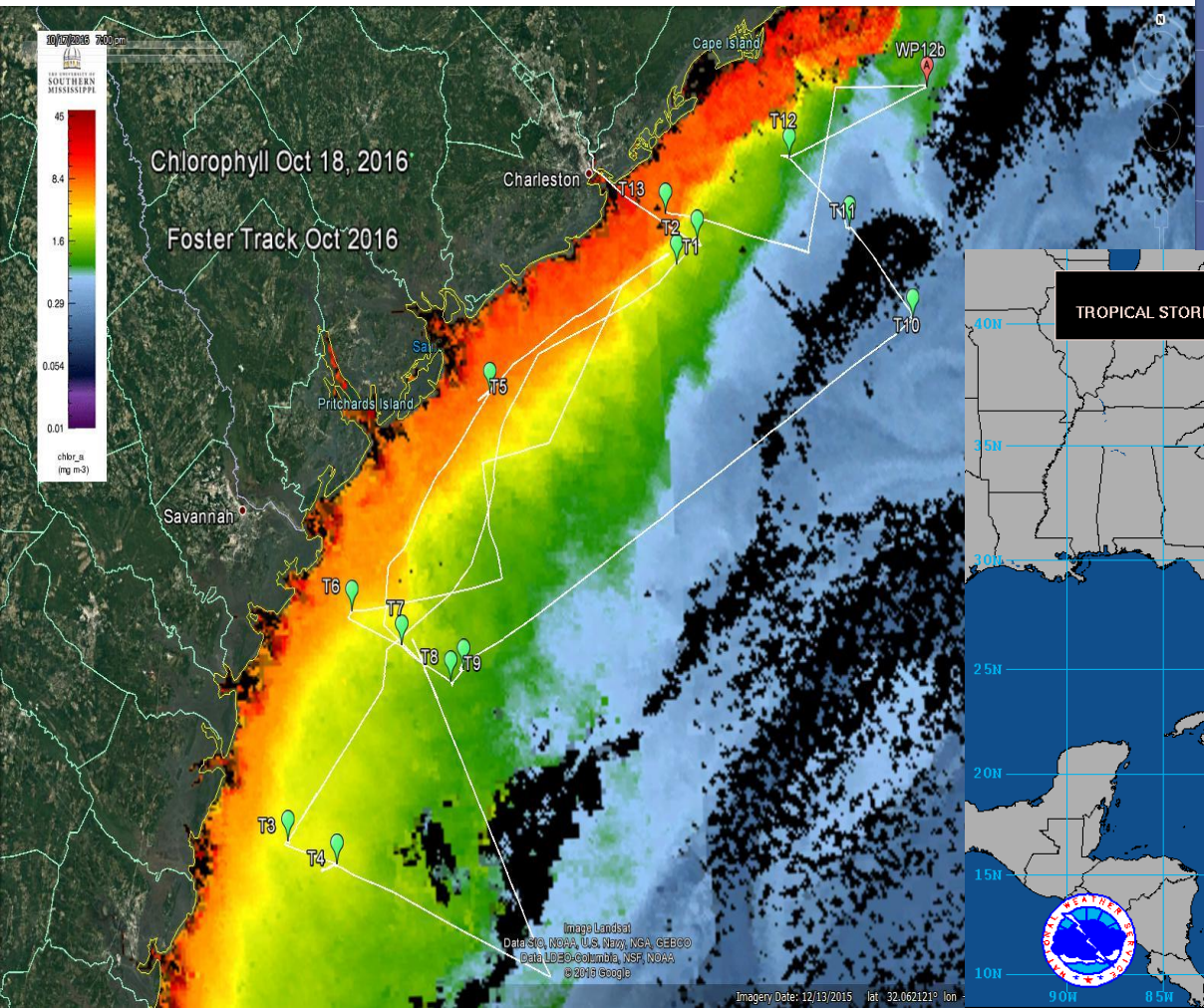


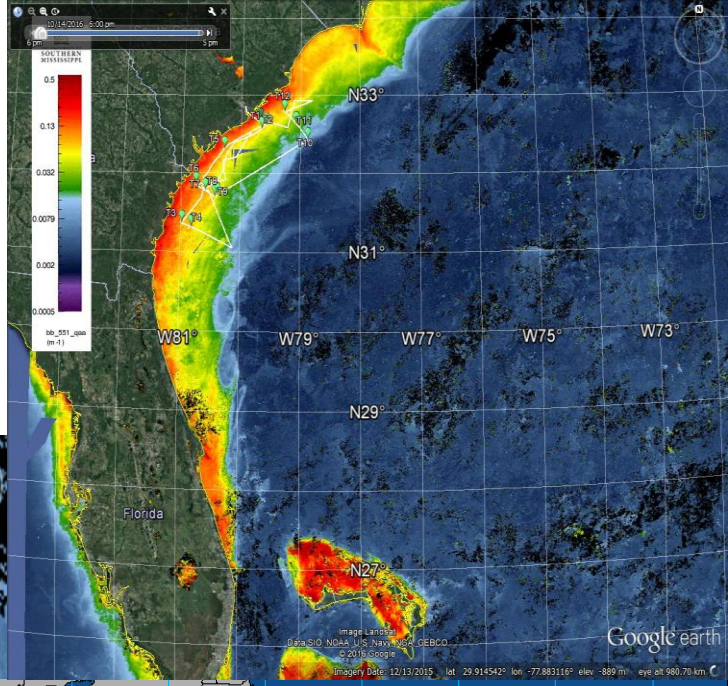
December 2015 Cal/Val Cruise

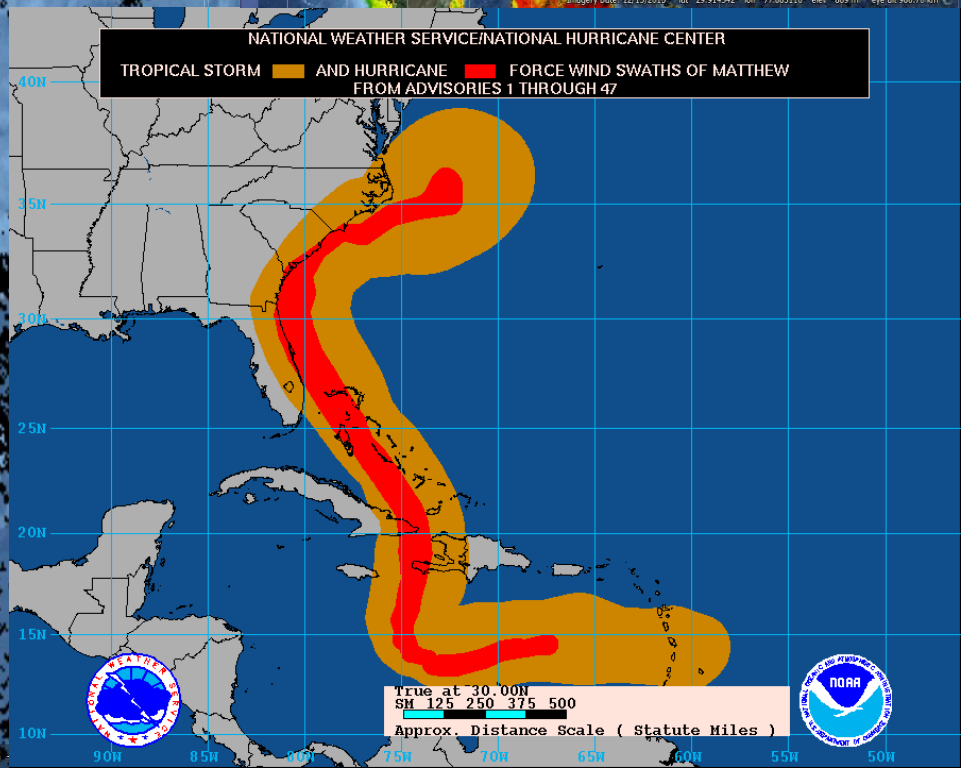


From: Arnone

VIIRS Cal/Val Cruise III (NF-16-08), October 5 to 18, 2016 aboard the NOAA Vessel Nancy Foster

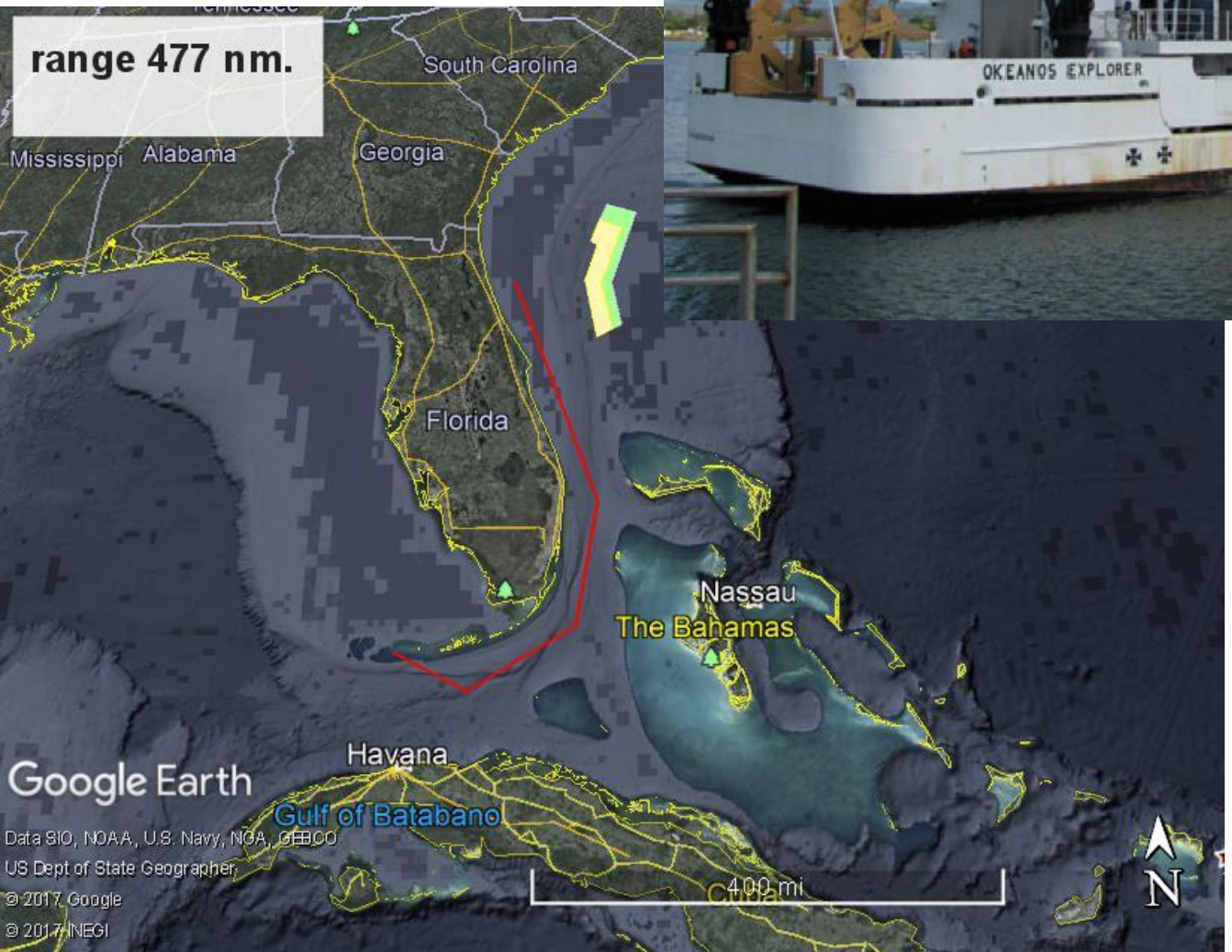






May 2018
Cal/Val Cruise



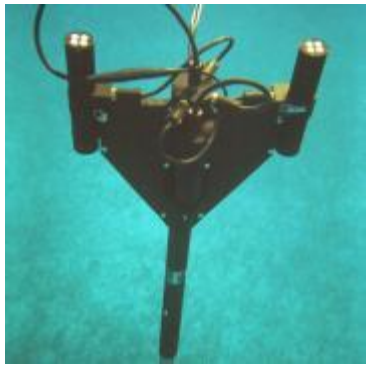


Instrument Shorthand	Full Identification/Purpose	Manufacturer or Citation
ac-9	In situ spectrophotometer - 9 channel resolution	WET Labs
ac-s	In situ spectrophotometer – high spectral resolution	WET Labs
ADCP	Acoustic Doppler Current Profiler	Teledyne RD Instruments
ASD	Analytical Spectral Device; HandHeld2-Pro visible and near infrared spectrophotometer	PANalytical
BB-3	Backscatter – 3 channels	
BB7FL2	Backscatter – 7 channels, Fluorescence – 2 channels	WET Labs
C-OPS	compact hyperspectral optical profiling system	Biospherical Instruments, Inc.
CTD	Conductivity, Temperature, Depth	Generic, various manufacturers
ECO-Puck Triplet Fluorometer	Fluorescence at 3 channels for determining chlorophyll, CDOM and phycoerythrin	WET Labs
ECO-Puck Triplet Scatterometer	Scatter – 3 channels (443, 550, 860)	WET Labs
GER	Field portable spectroradiometer	Spectra Vista Corporation
FlowCam	Dynamic imaging particle analysis for species composition and size measurements	Fluid Imaging Technologies, Inc.
HyperOCI	Hyperspectral irradiance sensor	Satlantic LP
HyperOCR	Hyperspectral radiance sensor	Satlantic LP
HyperPro, HyperPro-II	Free-falling hyperspectral optical profiler	Satlantic LP
HyperSAS	Above water optical system	Satlantic LP
HyperSAS-POL	Above water optical system with sky polarimeter	Satlantic LP with modifications by CCNY
HyperTSRB	Hyperspectral radiometer configured to float on the sea surface	Satlantic LP
Imaging Flow CytoBot (IFCB)	Automated microscopic imaging instrument	McLane Research Labs
Microtops	Handheld sun photometer (atmospheric aerosols and optical depth)	Solar Light Company
NURADS	Upwelling Radiance Distribution Camera System	Voss and Chapin, 2005
Sartorius CPA 2250	Balance	Sartorius
RISBA	Radiometer Incorporating the Sky Blocking Approach	Lee et al. 2013
SBE 49	Conductivity, Temperature, Depth	SeaBird Scientific
VSF-9	Volume scattering function – 9 channels	WET Labs
SR1900 (Spectral Evolution)	Spectroradiometer, handheld	Spectral Evolution, Inc.

Instruments used to measure Remote Sensing Reflectance

Profilers



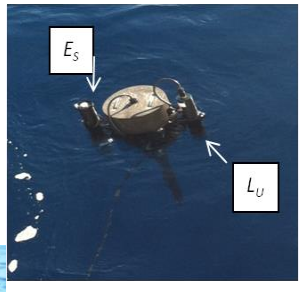


Hyp (Satlantic) – Hyperpro free-falling hyperspectral optical profiler. 10 nm bands sampled every 3 nm. Radiance FOV 8.5 degrees. Calibrated from 350 to 800 nm.



C-OPS (Biospherical Instruments, Inc.) – compact multispectral optical profiling system. a spectral range from 300 nm to 900 nm, with 19 wavebands wavelengths each: 305 nm, 320 nm, 340 nm, 380 nm, 395 nm, 412 nm, 443 nm, 465 nm, 490 nm, 510 nm, 532 nm, 555 nm, 565 nm, 625 nm, 665 nm, 683 nm, 710 nm, 780 nm, and 875 nm.

Instruments used to measure Remote Sensing Reflectance



Surface

Float (Satlantic) – HyperTSRB. Same instrument as hyperpro but collared to float at surface.



SBA (Satlantic) – Sky- Blocking Apparatus (SBA) radiometer package composed of one HyperOCR radiance sensor and one irradiance sensor. directly measures the water-leaving radiance Lw while blocking out sky-light (Lee et al., 2013).

Above-water

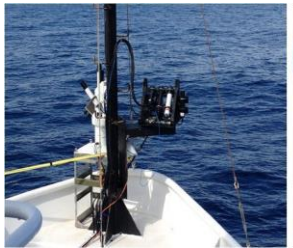


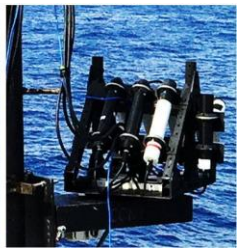
ASD Analytical Spectral Device (PANalytical) – Handheld 2 above-water spectrometer. Spectral range of 325 to 1075 nm. Spectral Resolution <3.0 nm, FOV 10 degrees. 2nd asd has 7 degrees FOV.



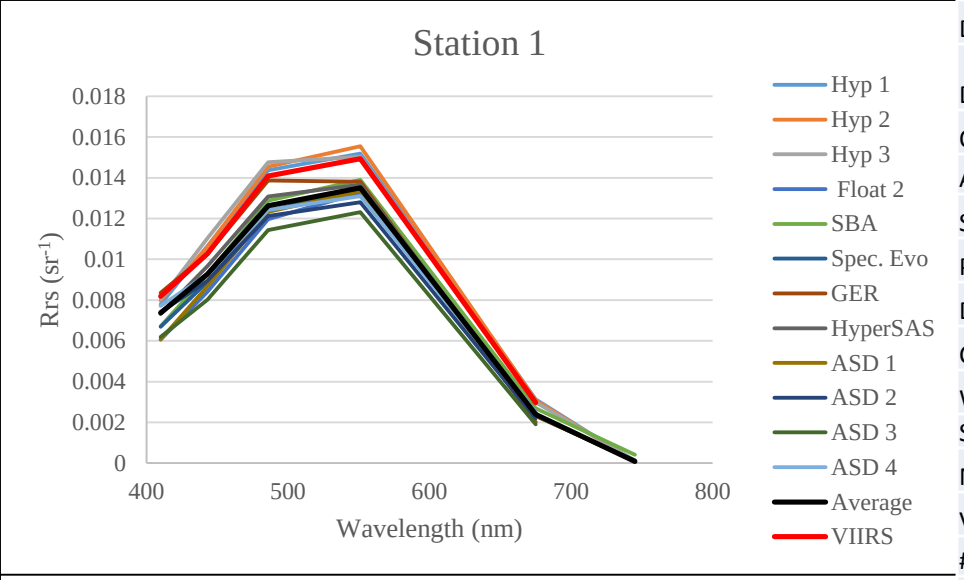
GER (Spectra Vista Corporation) – The GER 1500, Field Portable hand-held Spectroradiometer. Wavelengths from 350 nm to 1050 nm at 3 nm resolution with 4° nominal field of view (FOV).

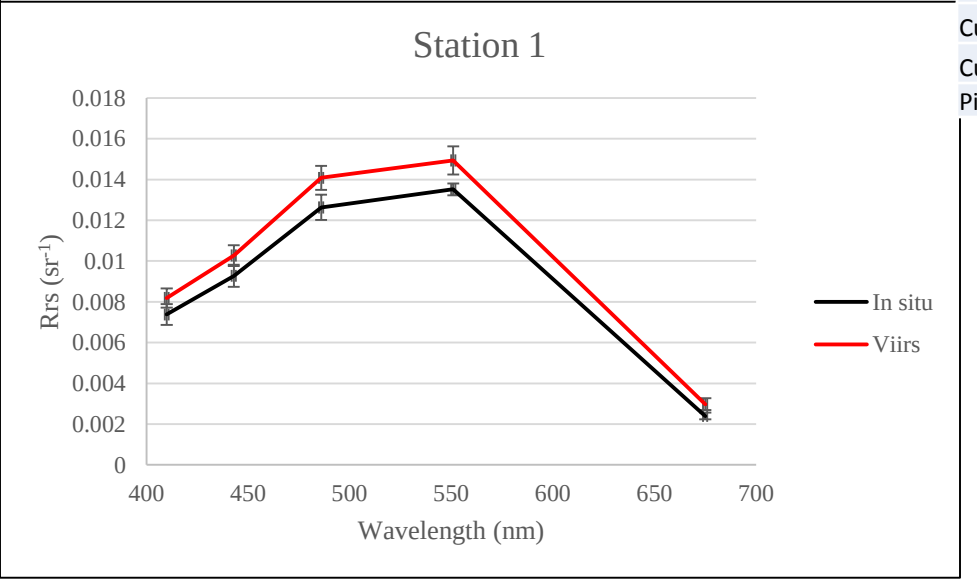
HyperSAS (Satlantic) – Autonomous above-water OCR's with narrow FOV of 3 degrees. Also set up to measure polarization



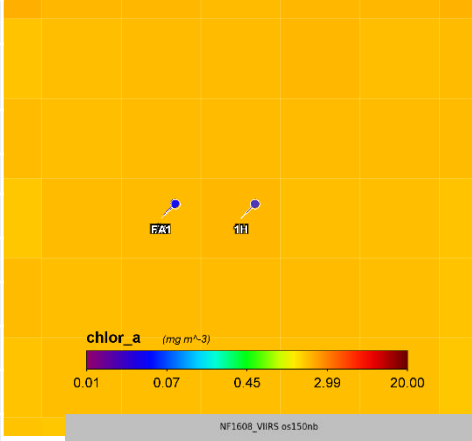


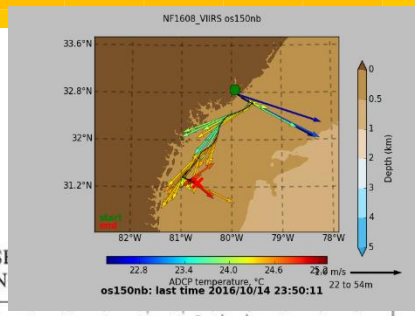
Spec-Evo – Spectral Evolution above water radiometer.

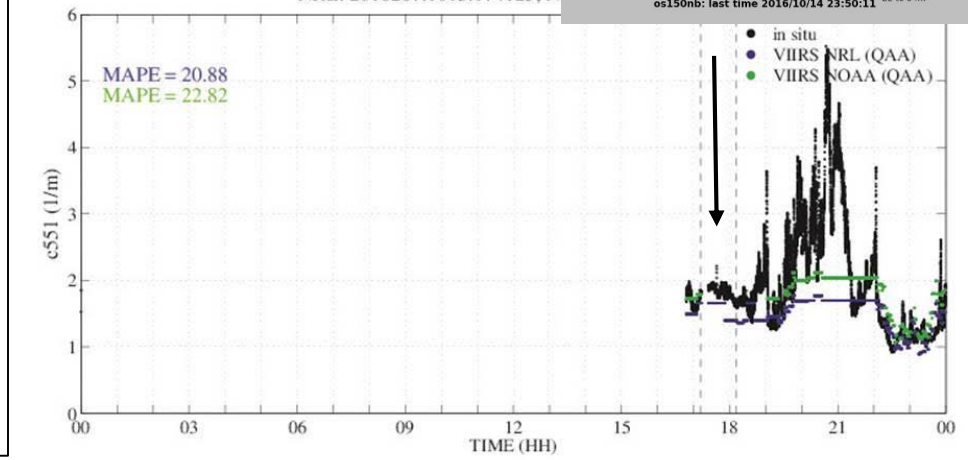




Date:	10/13, 287
Description:	Just off Charleston
Overpass time:	1740
Above time:	1843
Surf. Time:	1743
Profile time:	1720
Depth (m):	17
Cloud cover (%):	0
Wind speed (kts):	10
Seas (ft)	3
Meas. Chl (mg/m³)	1.39
VIIRS Chl (mg/m³)	2.02
# pixels in 5 x 5	21
Current (m/s):	0.5
Current source direction:	45
Pixel travel OP - sta	0

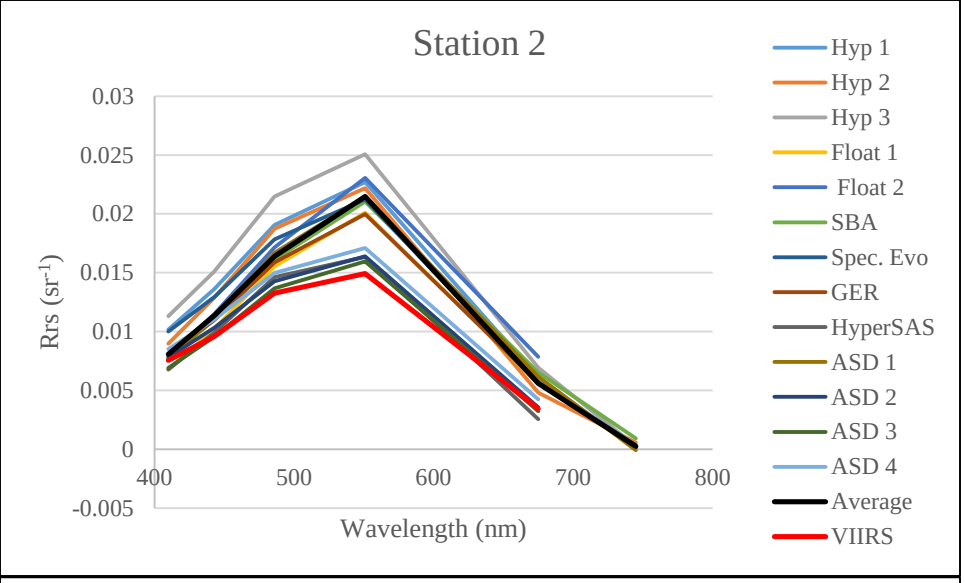


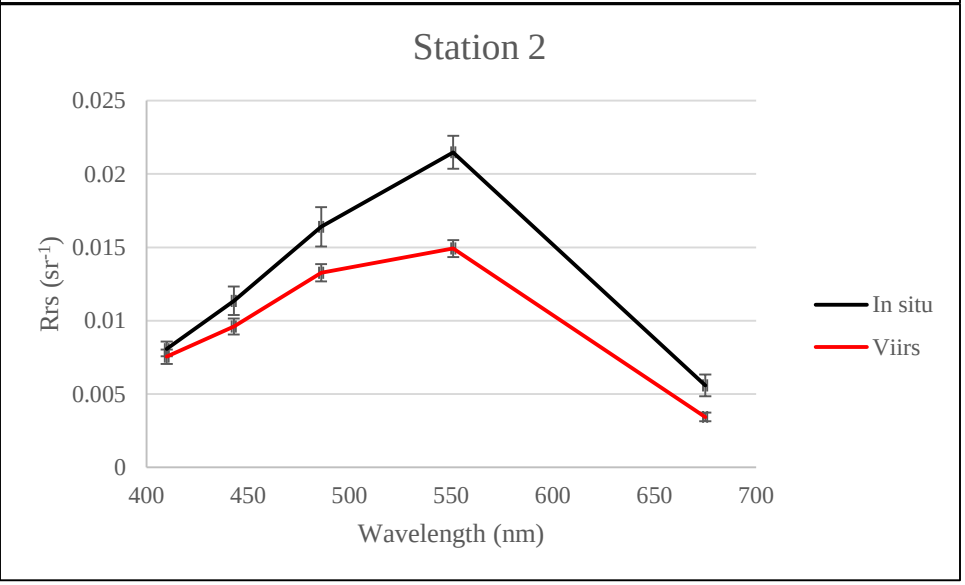




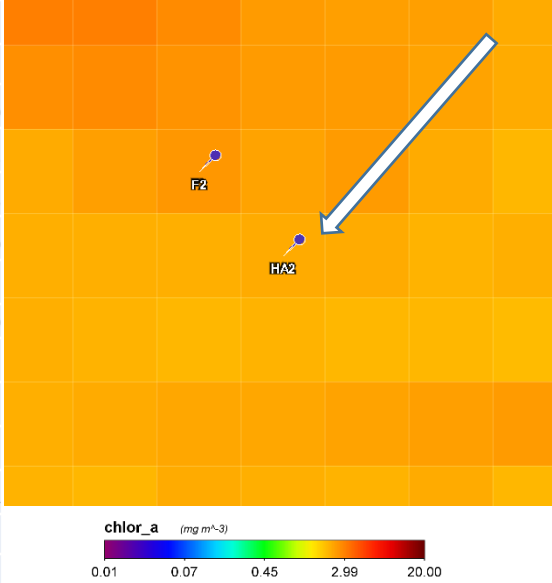
Percent difference relative to Average

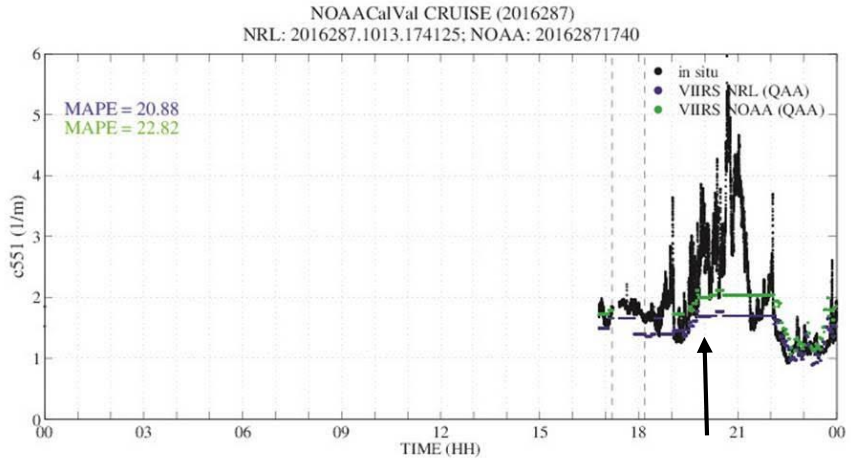
Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410	12.32	12.19	16.48		-11.18	-2.24	-6.13	-8.43	8.30	2.06	-5.56	-15.46	-2.35
443	10.47	11.73	13.41		-8.02	-0.99	-4.98	-5.27	6.59	0.51	-6.84	-12.10	-4.50
486	10.18	12.71	8.99		-3.70	0.83	-2.01	-3.32	0.10	-0.90	-7.21	-10.67	-5.01
551	25.84	23.64	20.16		-4.08	7.98	-7.15	-6.52	-19.45	-5.68	-11.61	-23.74	0.60
675	-40.25	-47.81	-4.85			217.45	-5.32	-19.23					





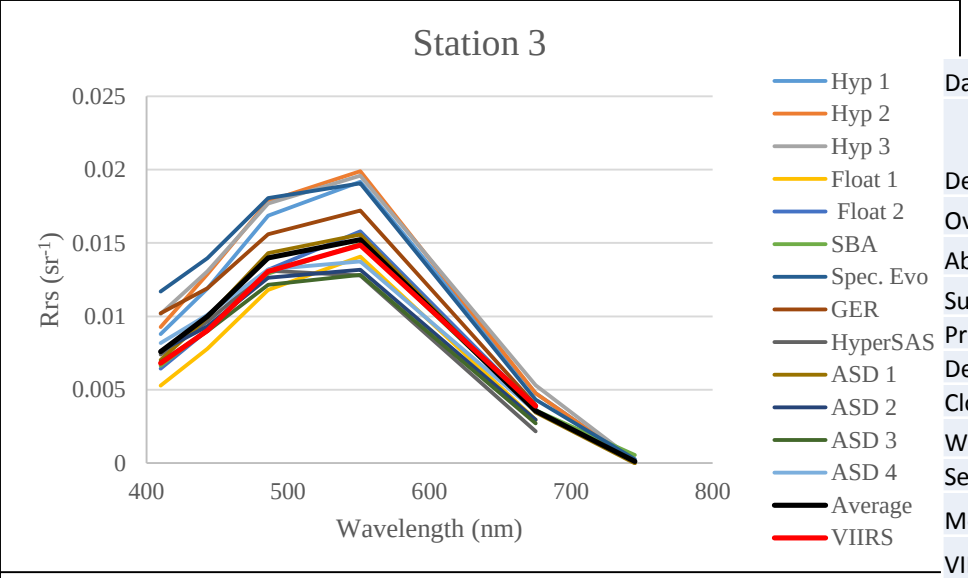
Date:	10/13, 287
Description:	8 km away
Overpass time:	1740
Above time:	2018
Surf. Time:	2046
Profile time:	2010
Depth (m):	17
Cloud cover (%):	0
Wind speed (kts):	9
Seas (ft)	3
Meas. Chl (mg/m³)	1.81
VIIRS Chl (mg/m³)	2.24
# pixels in 5 x 5	21
Current (m/s):	0.5
Current source direction:	45
Pixel travel OP - sta	5

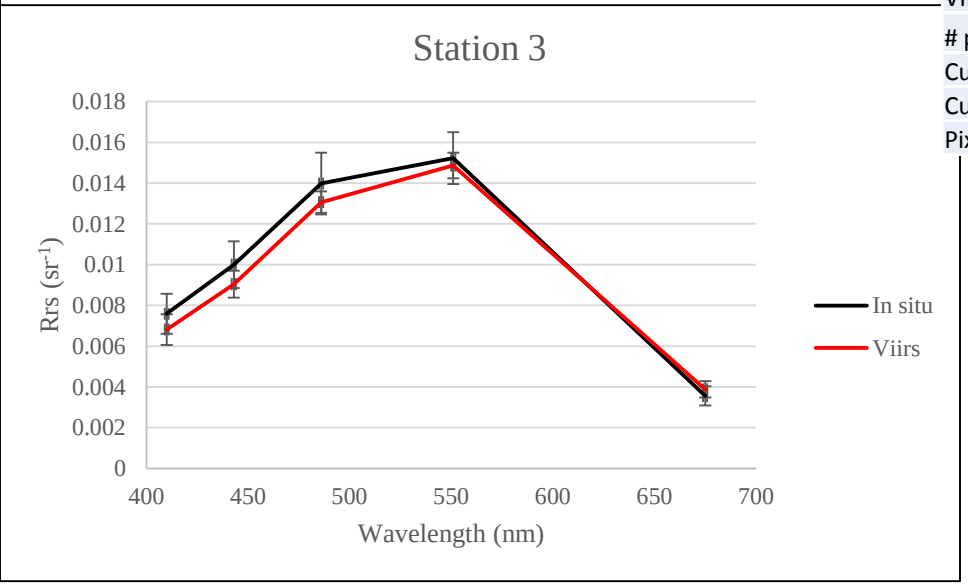




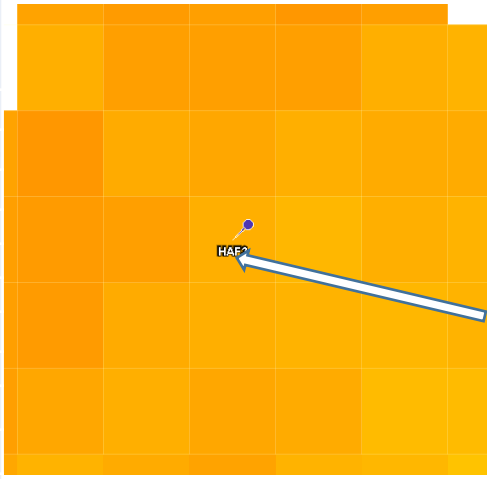
Percent difference relative to Average

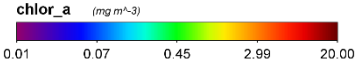
Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410	21.90	7.64	35.59	-18.54	-5.54	-7.79	19.86	-9.20	-3.30	-18.98	-6.45	-17.19	1.98
443	17.78	11.32	30.72	-11.56	-0.55	-4.68	11.87	-2.82	-5.04	-14.29	-10.76	-17.31	-4.68
486	14.66	12.65	29.19	-6.44	3.28	-3.04	7.36	0.51	-4.46	-12.00	-14.13	-17.68	-9.90
551	12.44	9.82	24.14	-0.54	14.06	4.18	5.15	6.19	-1.04	-19.07	-18.88	-21.06	-15.39
675	15.00	-9.10	30.90	4.92	48.40	23.09	7.51	16.31	6.84	-51.95	-33.12	-38.96	-19.84

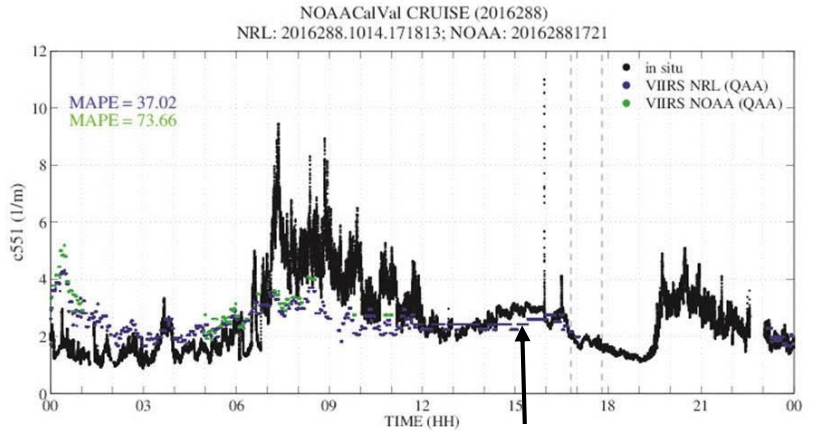




Date:	10/14, 288
Description:	17 miles off Savannah
Overpass time:	1901
Above time:	1600
Surf. Time:	1535
Profile time:	1531
Depth (m):	18
Cloud cover (%):	15
Wind speed (kts):	9
Seas (ft)	3
Meas. Chl (mg/m³)	1.846
VIIRS Chl (mg/m³)	2.18
# pixels in 5 x 5	22
Current (m/s):	0.2
Current source direction:	100
Pixel travel OP - sta	4

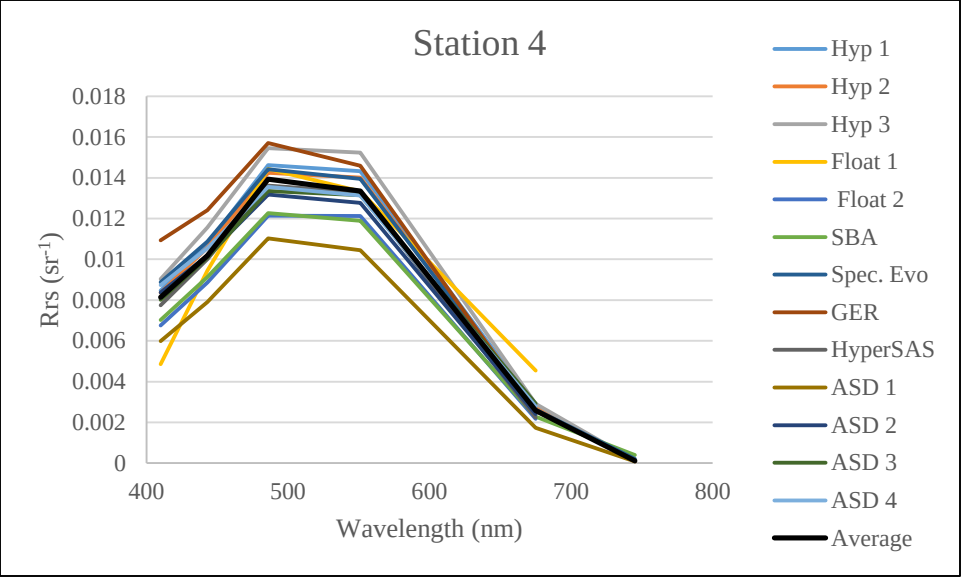


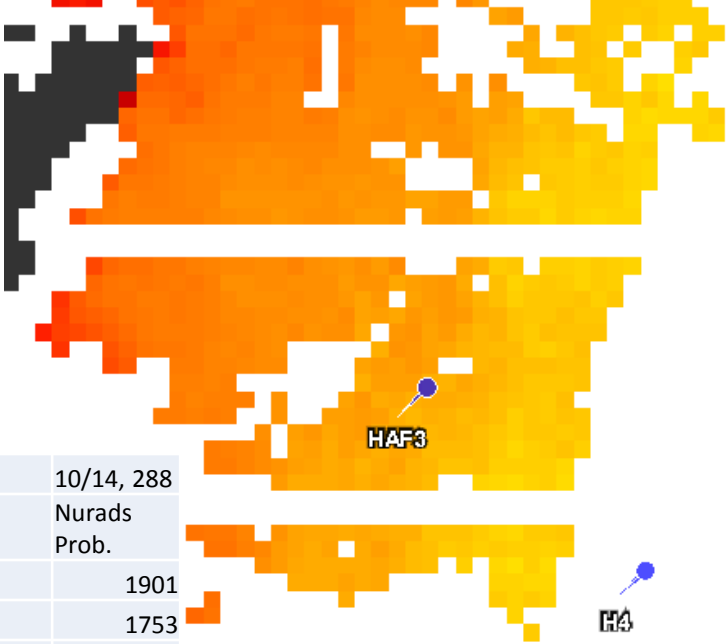




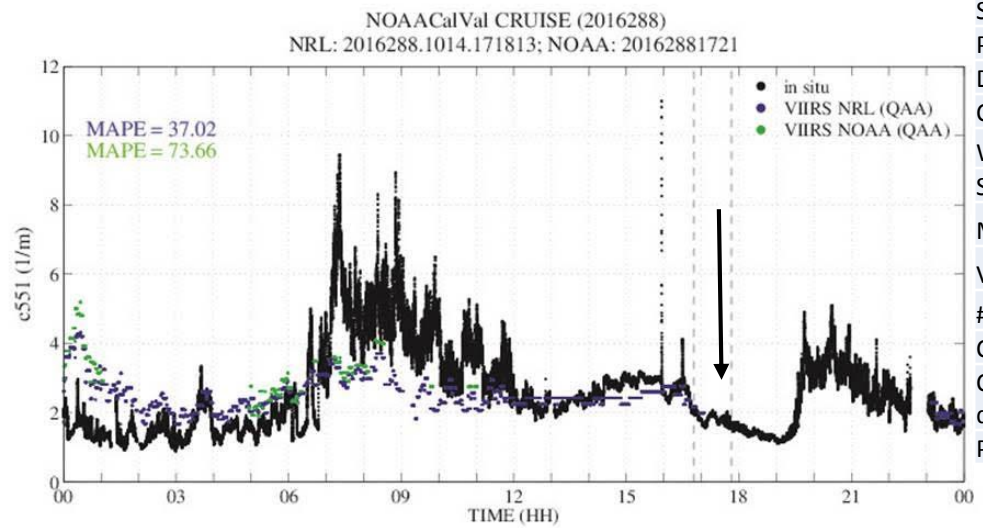
Percent difference relative to Average

Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410	8.23	14.04	25.20	-35.02	-20.74	-18.29	43.86	-13.54	25.70	-8.91	-6.10	-15.23	0.80
443	12.37	21.56	23.50	-26.52	-14.44	-13.99	31.82	-6.16	12.54	-8.96	-12.10	-15.01	-4.61
486	15.75	22.52	21.48	-18.98	-9.53	-11.35	24.00	-1.75	7.02	-9.95	-13.26	-16.58	-9.40
551	19.94	24.39	22.55	-11.96	-1.27	-6.53	19.20	-2.55	7.67	-20.00	-17.58	-19.80	-14.07
675	28.50	28.20	43.02	-20.69	1.09	-2.53	16.65	-7.04	6.52	-41.64	-20.19	-26.84	-5.04

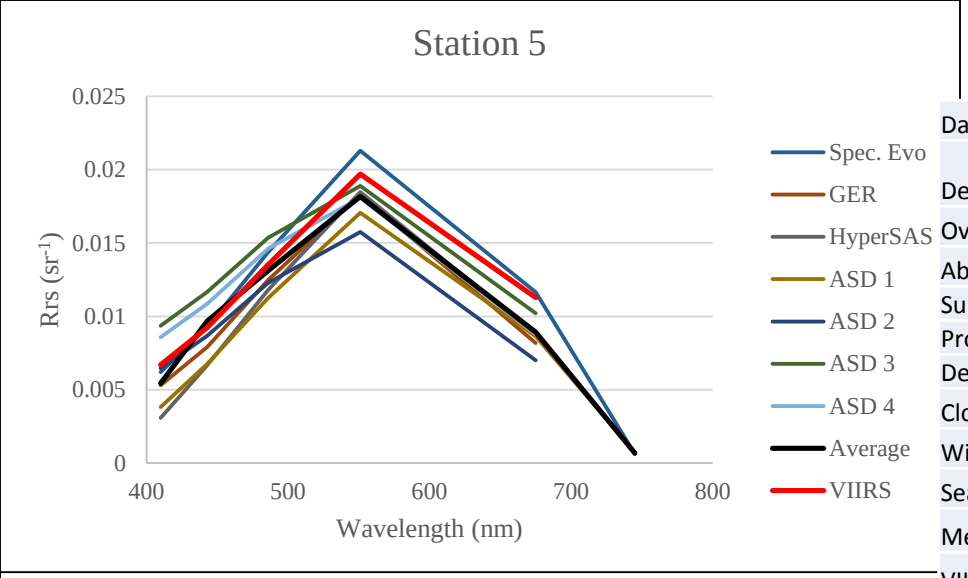




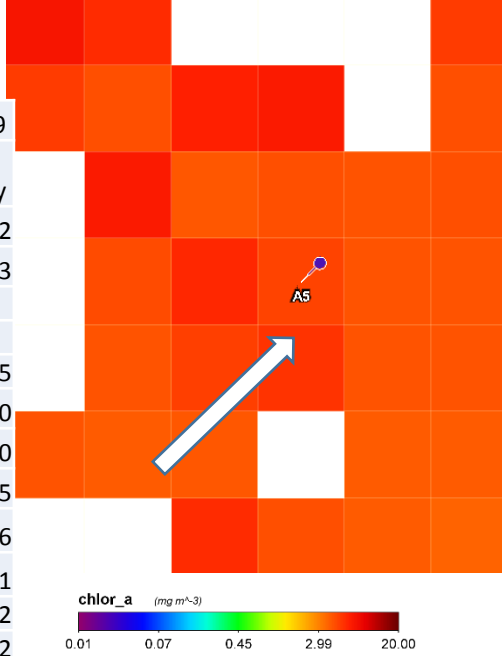
Date:	10/14, 288
Description:	Nurads Prob.
Overpass time:	1901
Above time:	1753
Surf. Time:	1840
Profile time:	1753
Depth (m):	9
Cloud cover (%):	50
Wind speed (kts):	15
Seas (ft)	5
Meas. Chl (mg/m^3)	1.84
VIIRS Chl (mg/m^3)	N/A
# pixels in 5 x 5	N/A
Current (m/s):	N/A
Current source direction:	N/A
Pixel travel OP - sta	N/A

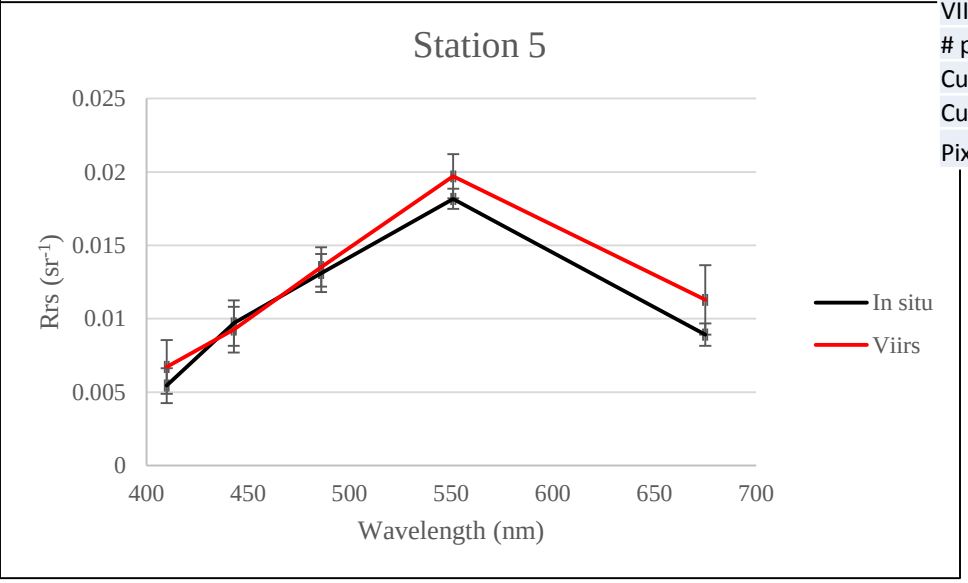


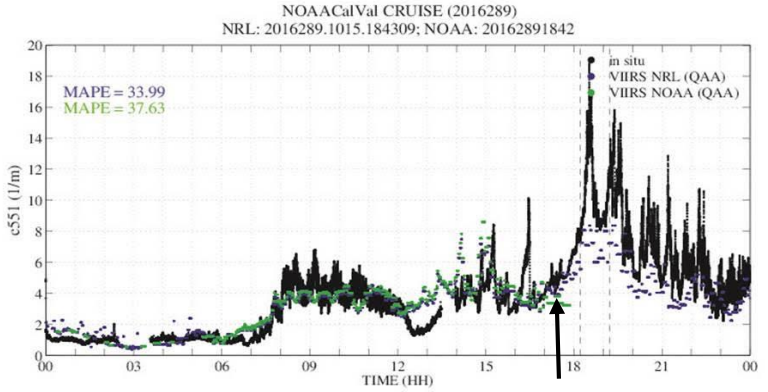
Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410	6.67	5.29	13.94	-38.83	-14.83	-11.51	11.78	-24.50	37.70	-2.37	5.49	1.00	10.16
443	5.75	3.86	13.56	-7.29	-12.90	-10.38	6.84	-22.29	21.90	-1.77	-0.03	-0.86	3.60
486	6.84	3.98	12.89	5.43	-11.35	-10.44	5.32	-19.49	14.64	-0.54	-3.75	-2.48	-1.05
551	8.13	5.75	15.01	0.65	-8.45	-10.27	5.31	-21.18	10.06	0.32	-3.66	-0.79	-0.87
675	5.25	1.96	9.26	70.52	-18.49	-14.66	-1.35	-35.03	-5.51	-16.28	-9.73	9.93	4.14



Date:	10/15, 289
Description:	Windy, above only
Overpass time:	1842
Above time:	1843
Surf. Time:	none
Profile time:	none
Depth (m):	15
Cloud cover (%):	40
Wind speed (kts):	20
Seas (ft)	5
Meas. Chl (mg/m³)	5.466
VIIRS Chl (mg/m³)	4.81
# pixels in 5 x 5	22
Current (m/s):	0.2
Current source direction:	225
Pixel travel OP - sta	0

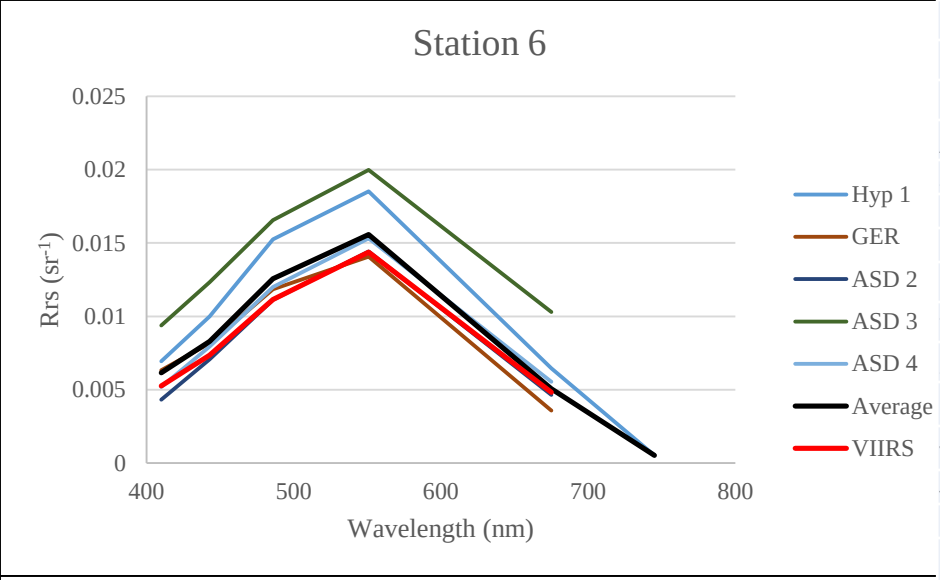




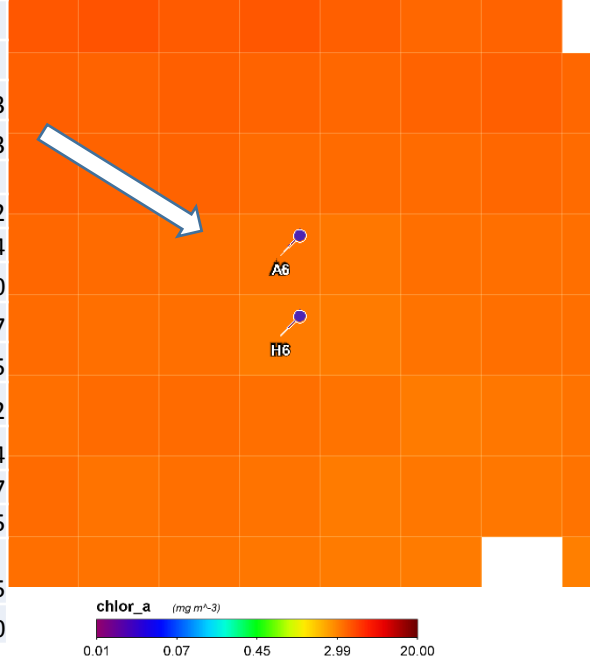


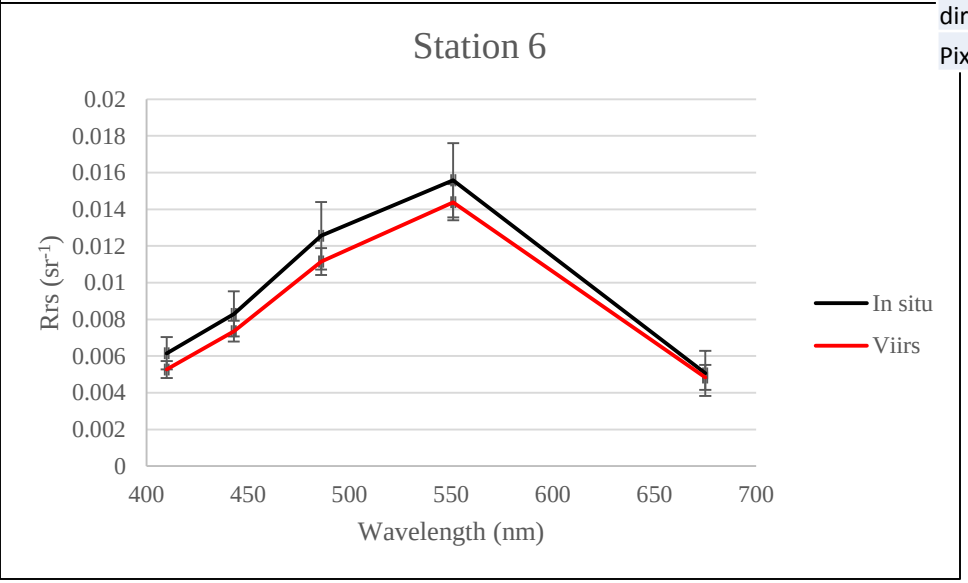
Percent difference relative to Average

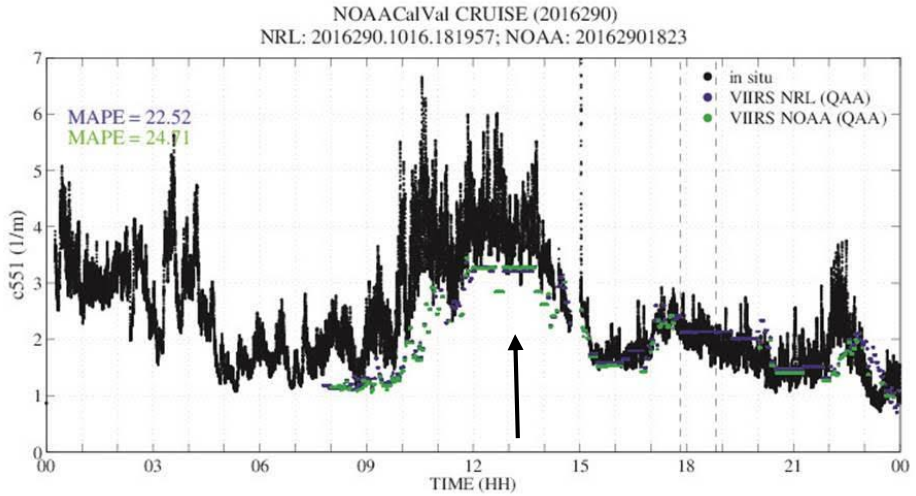
Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410							1.52	-37.42	-13.27	-49.72	5.60	53.03	40.26
443							5.21	-23.40	-10.35	-24.53	-1.81	31.91	22.96
486							9.15	-14.44	-5.28	-10.33	-6.71	16.62	11.00
551							16.54	-6.60	0.18	1.16	-13.76	3.46	-0.98
675							29.03	-4.41	-9.32	-2.94	-22.44	12.97	-2.89



Date:	10/16, 290
Description:	Windy,
Overpass time:	1823
Above time:	1343
Surf. Time:	none
Profile time:	1352
Depth (m):	14
Cloud cover (%):	50
Wind speed (kts):	17
Seas (ft)	5
Meas. Chl (mg/m³)	2.62
VIIRS Chl (mg/m³)	3.24
# pixels in 5 x 5	17
Current (m/s):	0.5
Current source direction:	315
Pixel travel OP - sta	10

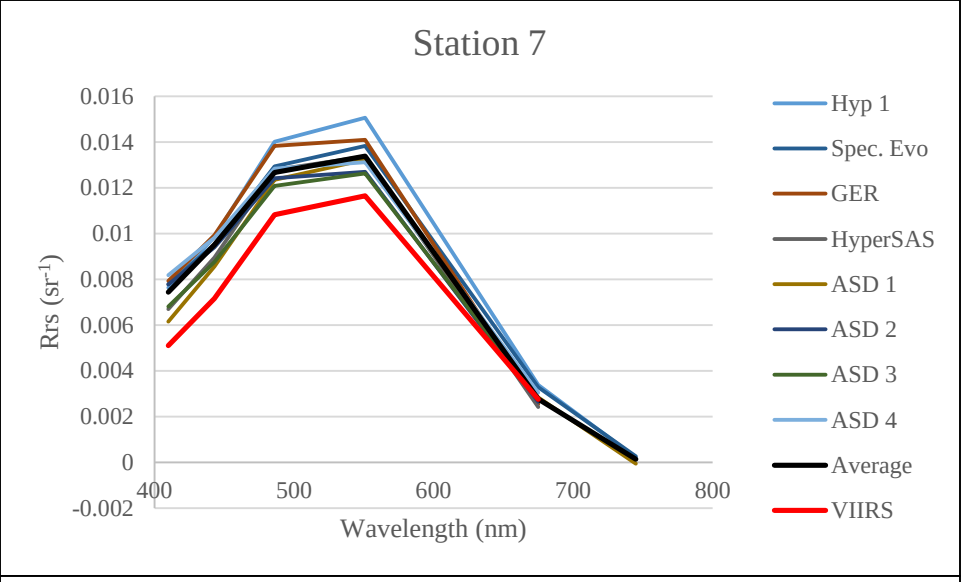


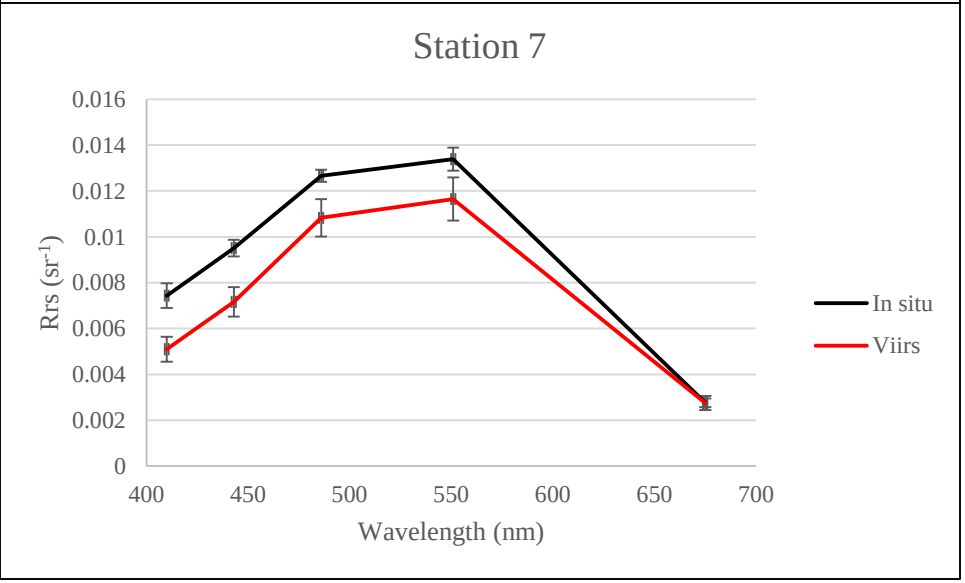




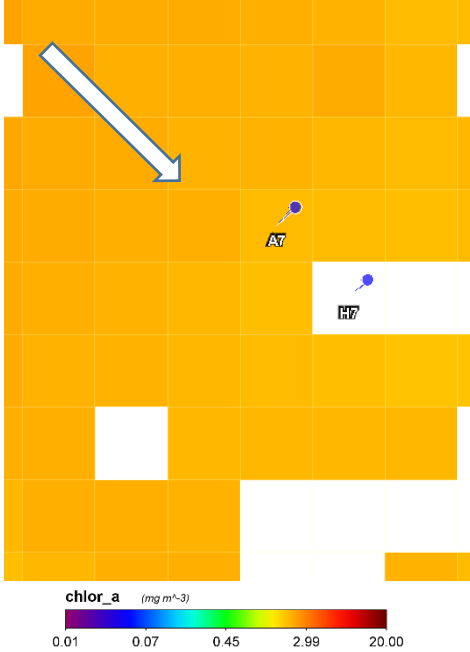
Percent difference relative to Average

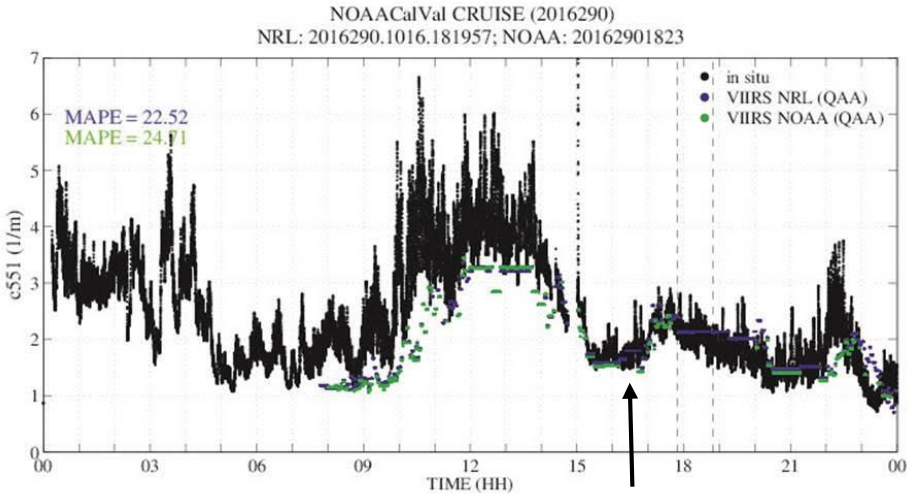
Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410	7.84								-1.67		-32.79	45.73	-19.11
443	9.83								-10.33		-22.30	35.42	-12.63
486	14.26								-11.36		-16.70	23.90	-10.11
551	12.48								-14.48		-12.35	21.35	-7.00
675	5.67								-41.30		-23.66	68.53	-9.24





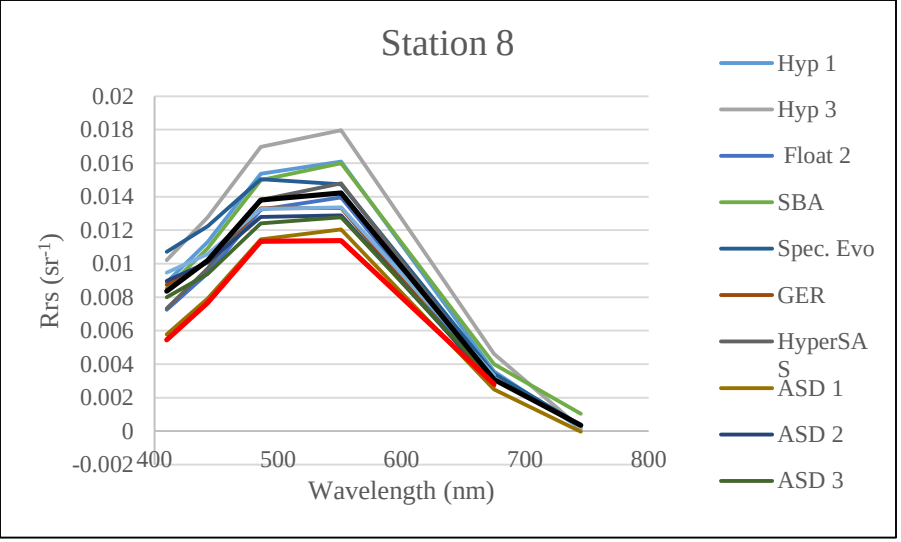
Date:	10/16, 290
Description:	Windy,
Overpass time:	1823
Above time:	1600
Surf. Time:	none
Profile time:	1625
Depth (m):	14
Cloud cover (%):	50
Wind speed (kts):	17
Seas (ft)	6
Meas. Chl (mg/m³)	1.47
VIIRS Chl (mg/m³)	1.9
# pixels in 5 x 5	20
Current (m/s):	0.5
Current source direction:	335
Pixel travel OP - sta	4



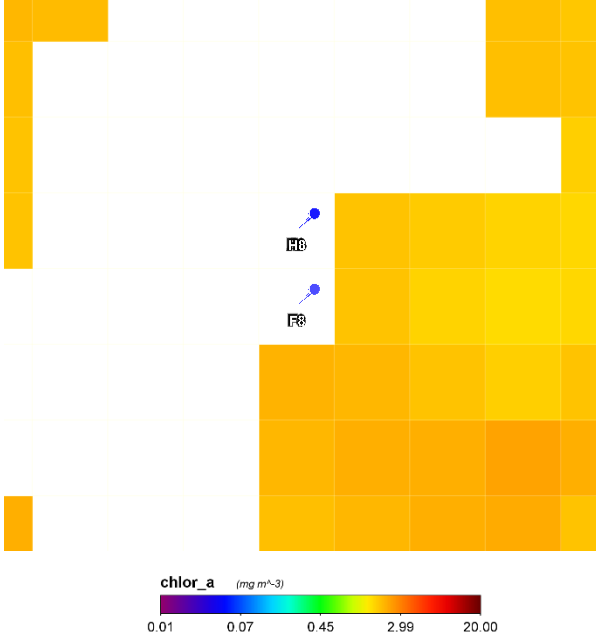


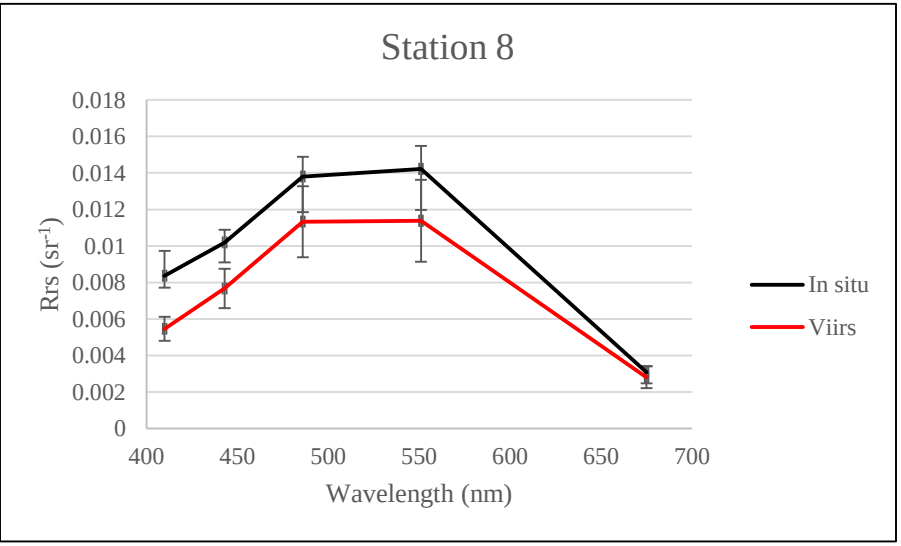
Percent difference relative to Average

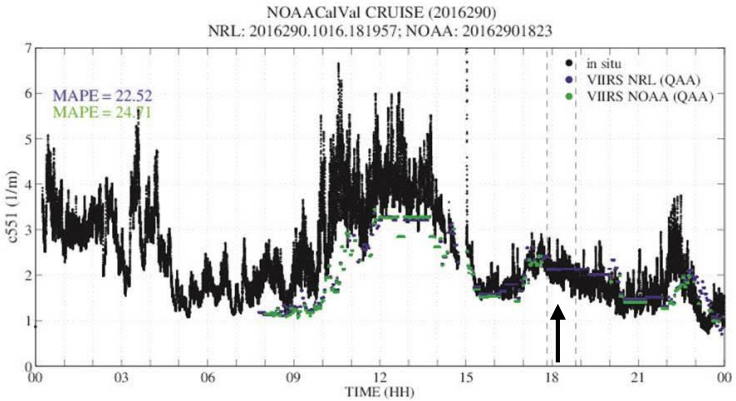
Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410	3.51						5.68	-16.53	7.66	-9.18	5.45	-7.60	11.03
443	5.46						1.88	-8.40	6.19	-4.24	0.53	-6.36	4.92
486	8.58						0.19	-4.32	7.21	-0.99	-3.75	-6.36	-0.56
551	11.52						2.41	-2.05	4.41	-1.00	-5.92	-6.51	-2.87
675	18.24						14.54	-1.07	-11.14	-15.58	-8.01	-3.33	6.35



Date:	10/16, 290
Description:	Off Savannah
Overpass time:	1823
Above time:	1803
Surf. Time:	1830
Profile time:	1803
Depth (m):	18
Cloud cover (%):	40
Wind speed (kts):	19
Seas (ft)	5
Meas. Chl (mg/m³)	1.59
VIIRS Chl (mg/m³)	1.9
# pixels in 5 x 5	7
Current (m/s):	0.3
Current source direction:	0
Pixel travel OP - sta	0

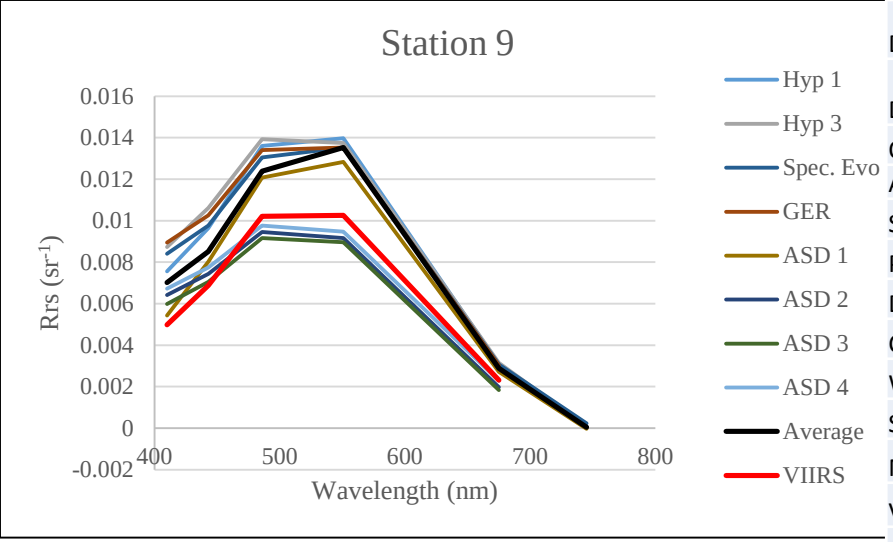




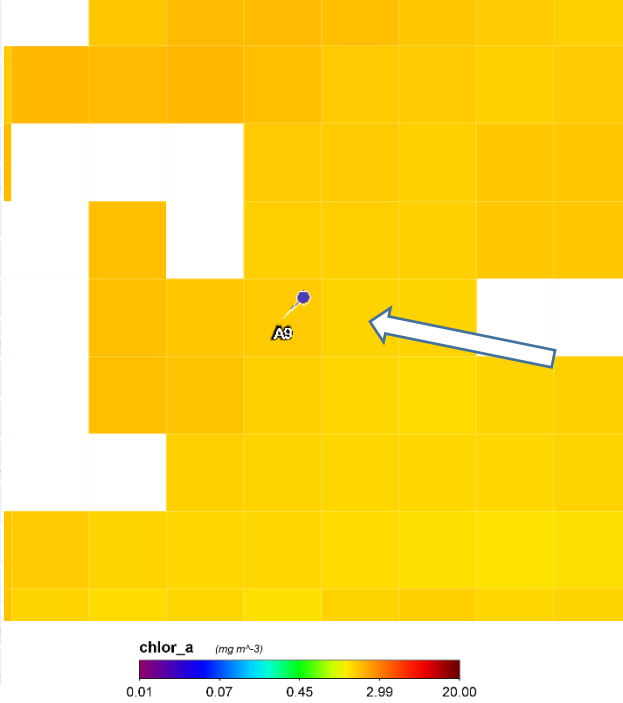


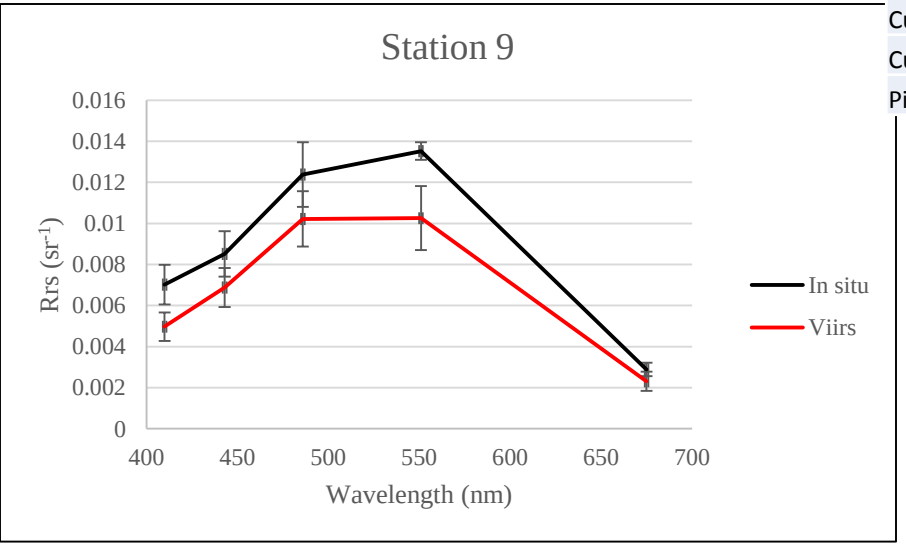
Percent difference relative to Average

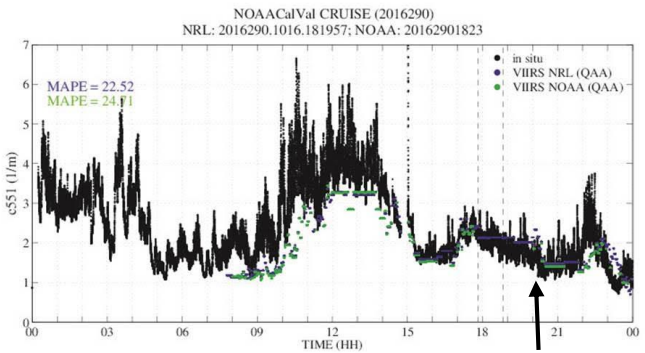
Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410	4.29		19.67		-14.94	-0.12	25.48	-32.22	2.35	-14.25	5.18	-6.29	10.85
443	8.53		22.67		-9.32	4.91	17.60	-23.83	-2.84	-6.60	-3.05	-9.66	1.60
486	10.78		22.29		-4.66	8.04	8.46	-17.47	-4.07	-0.57	-7.86	-10.57	-4.37
551	12.09		25.17		-2.84	11.45	2.60	-16.15	-7.20	3.08	-10.27	-11.03	-6.90
675	9.57		42.06		-13.97	23.07	5.67	-23.32	-17.22	-7.14	-12.45	-8.71	2.44



Date:	10/16, 290
Description:	Off Savannah
Overpass time:	1823
Above time:	2054
Surf. Time:	none
Profile time:	2015
Depth (m):	18.7
Cloud cover (%):	20
Wind speed (kts):	5
Seas (ft)	5
Meas. Chl (mg/m³)	1.34
VIIRS Chl (mg/m³)	1.78
# pixels in 5 x 5	18
Current (m/s):	0.7
Current source direction:	100
Pixel travel OP - sta	4

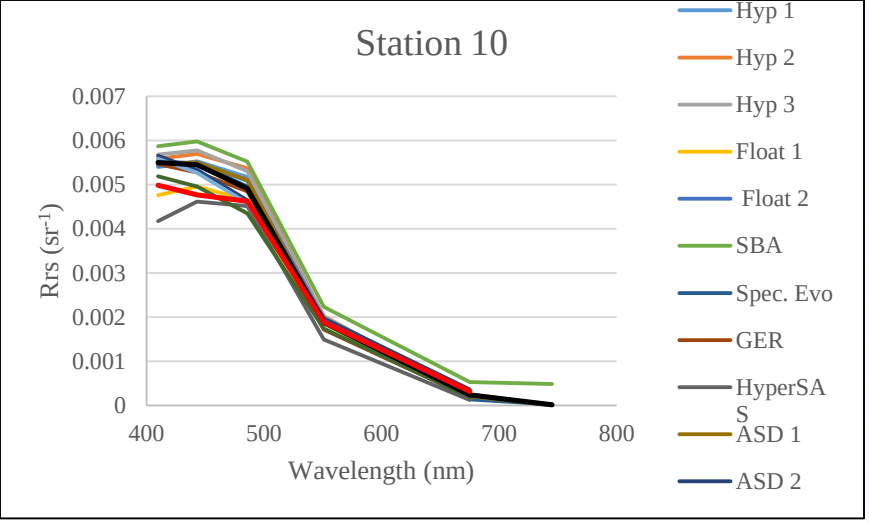


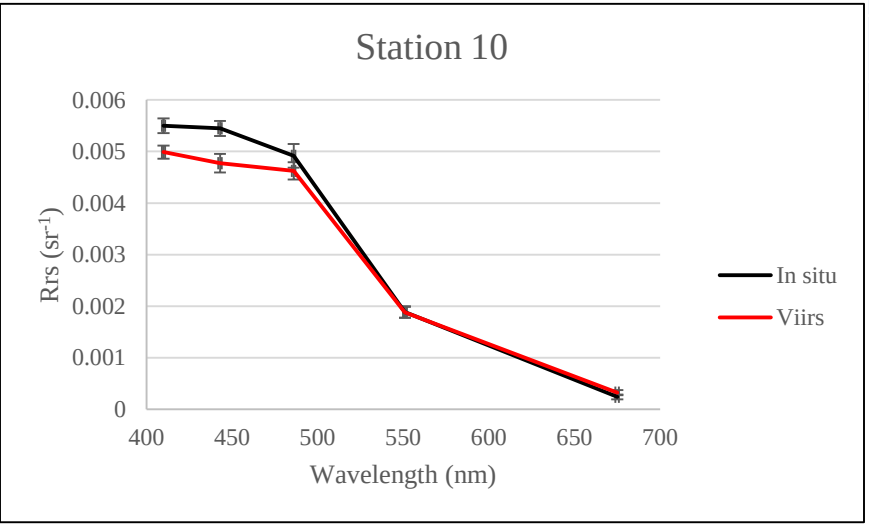




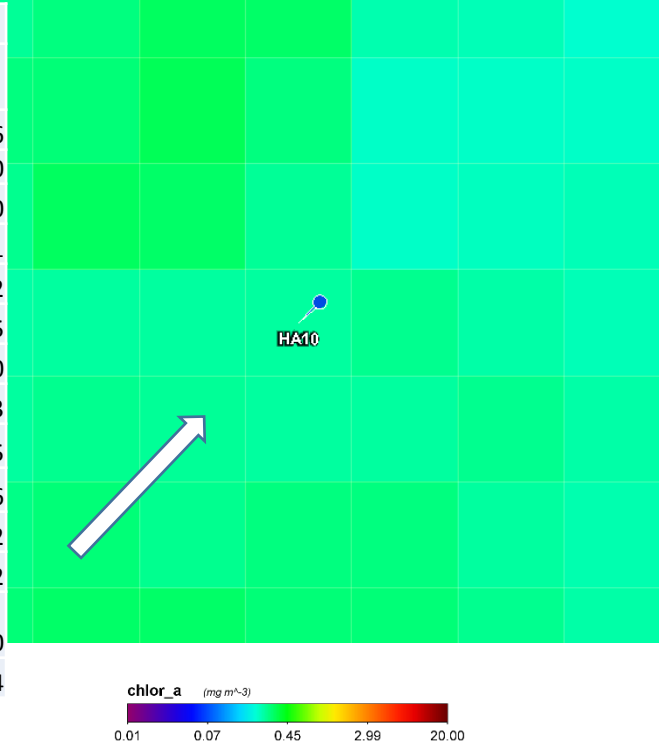
Percent difference relative to Average

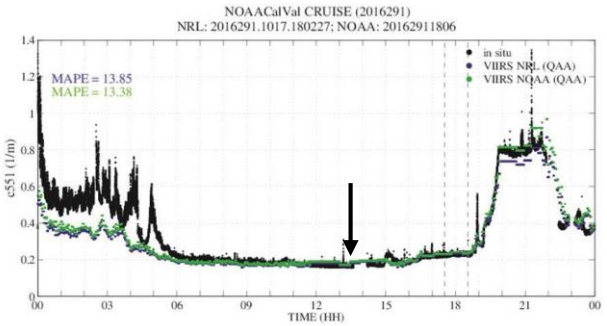
Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410	3.94		19.98				15.62	-25.38	22.95		-11.81	-17.74	-7.57
443	9.43		20.48				10.82	-9.10	16.33		-15.75	-19.96	-12.24
486	15.29		17.96				10.57	2.32	13.51		-19.95	-22.38	-17.33
551	17.47		15.48				13.62	7.85	13.64		-22.96	-24.73	-20.37
675	16.24		19.28				16.23	2.92	14.48		-25.24	-30.34	-13.55





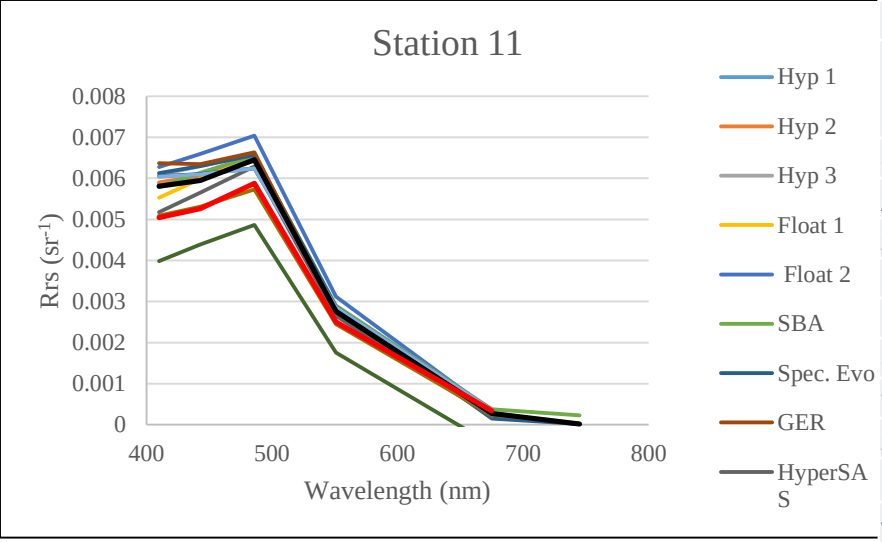
Date:	10/17, 291
Description:	Good offshore conditions
Overpass time:	1806
Above time:	1340
Surf. Time:	1420
Profile time:	1341
Depth (m):	92
Cloud cover (%):	5
Wind speed (kts):	10
Seas (ft)	3
Meas. Chl (mg/m³)	2.15
VIIRS Chl (mg/m³)	0.26
# pixels in 5 x 5	22
Current (m/s):	0.2
Current source direction:	210
Pixel travel OP - sta	4



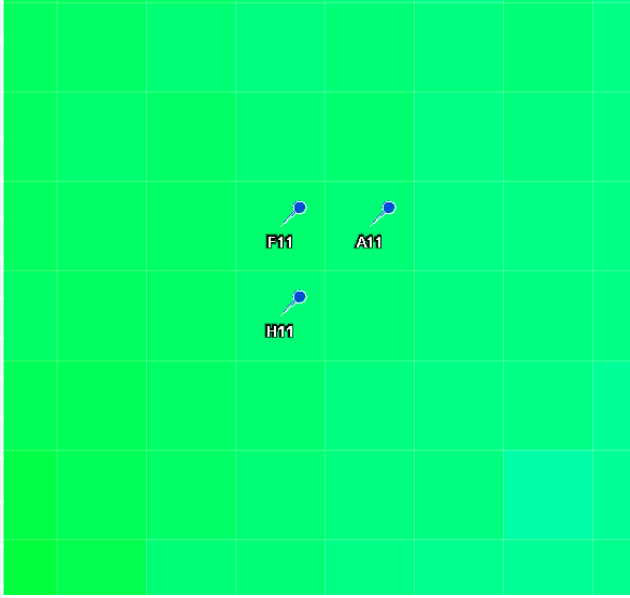


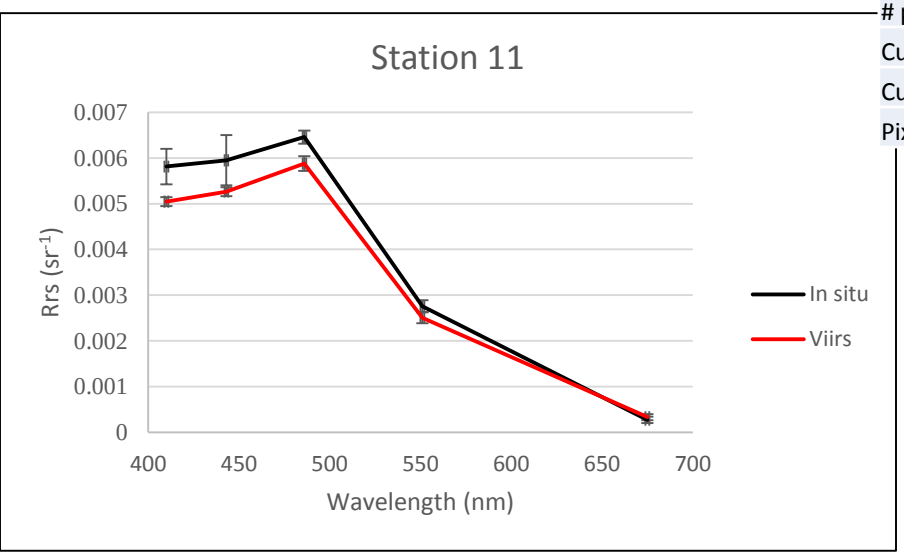
Percent difference relative to Average

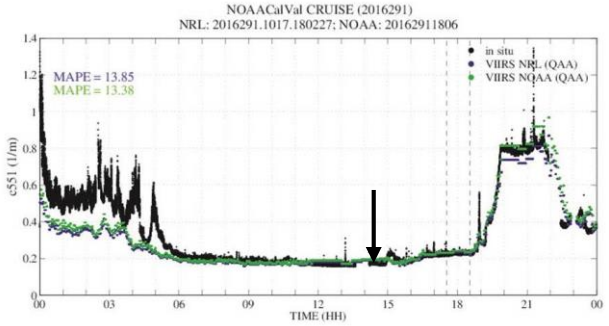
Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410	0.50	4.10	5.82	-11.36	1.06	9.29	3.03	2.14	1.78	-22.24	5.22	-3.34	4.00
443	2.89	5.96	7.47	-7.78	2.41	11.25	1.93	2.35	-1.81	-14.17	-0.76	-7.78	-1.97
486	4.97	8.85	7.61	-5.77	3.18	12.00	0.56	3.46	-1.64	-8.51	-5.78	-11.82	-7.10
551	3.51	7.42	6.50	-7.80	3.80	18.47	0.65	-1.23	-8.55	-20.72	4.58	-7.75	1.11
675	-6.43	-18.24	-3.45	-0.26	27.97	107.62	-46.07	-20.33	-25.11	-51.91	43.21	-24.45	17.45



Date:	10/17, 291
Description:	Good offshore conditions
Overpass time:	1806
Above time:	1733
Surf. Time:	1800
Profile time:	1733
Depth (m):	27
Cloud cover (%):	5
Wind speed (kts):	9.9
Seas (ft)	2
Meas. Chl (mg/m³)	0.328
VIIRS Chl (mg/m³)	0.307
# pixels in 5 x 5	22
Current (m/s):	0.2
Current source direction:	0
Pixel travel OP - sta	0

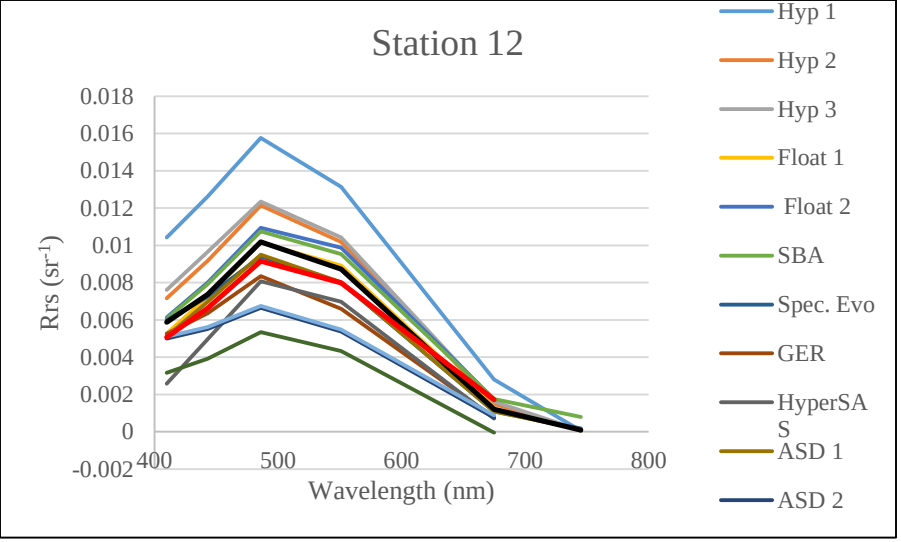


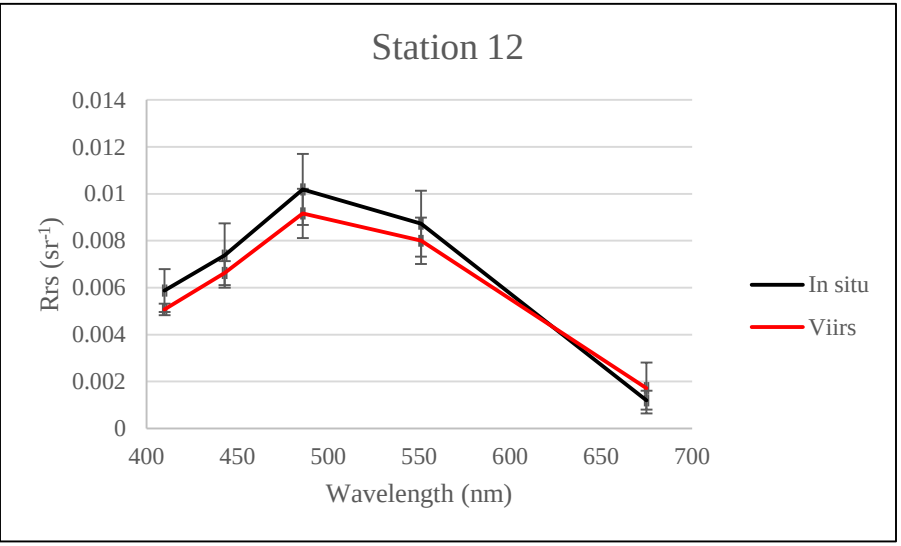




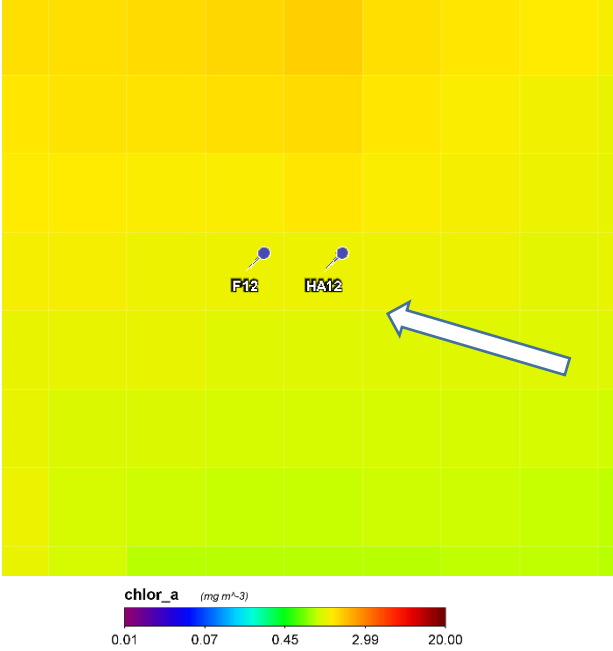
Percent difference relative to Average

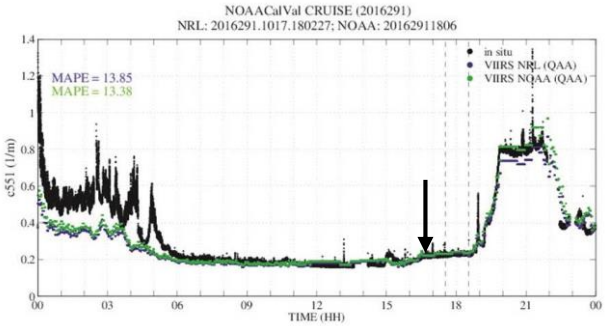
Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410	2.70	3.32	6.37	-3.26	9.78	1.21	7.25	-10.89	11.49	-9.36	5.86	-30.28	5.81
443	1.85	1.85	5.83	0.69	10.81	3.12	5.87	-10.73	6.71	-4.92	2.58	-26.18	2.53
486	1.59	2.91	4.20	2.68	11.36	3.60	3.96	-9.35	4.90	-0.44	-1.17	-23.01	-1.23
551	-0.58	1.11	4.80	2.80	15.07	7.15	5.61	-9.50	0.54	-2.26	5.32	-35.26	5.20
675	22.40	4.95	26.72	34.83	46.51	71.51	-32.88	10.56	20.73	-11.89	65.14	-322.21	63.62





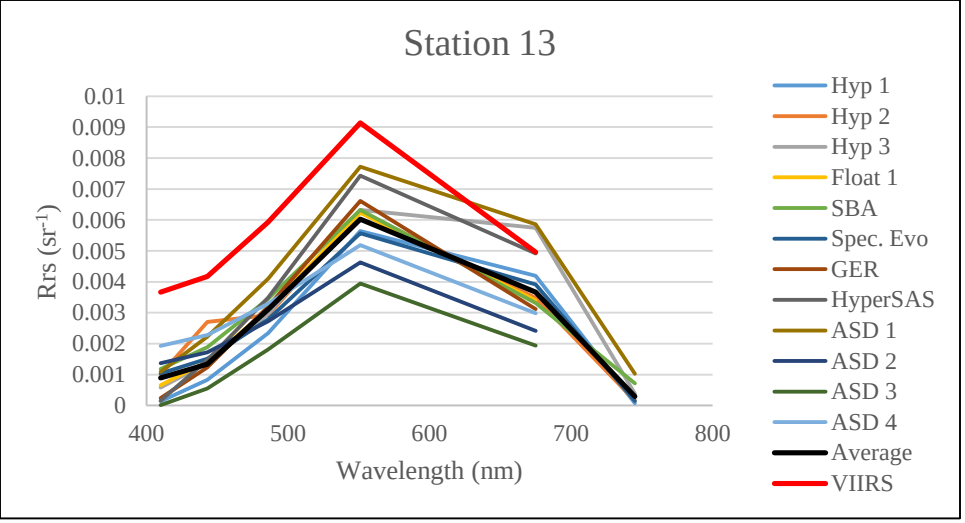
Date:	10/17, 291
Description:	Good offshore conditions
Overpass time:	1806
Above time:	2015
Surf. Time:	2045
Profile time:	2015
Depth (m):	35
Cloud cover (%):	0
Wind speed (kts):	8
Seas (ft)	2
Meas. Chl (mg/m³)	0.591
VIIRS Chl (mg/m³)	1.23
# pixels in 5 x 5	22
Current (m/s):	0.2
Current source direction:	100
Pixel travel OP - sta	2



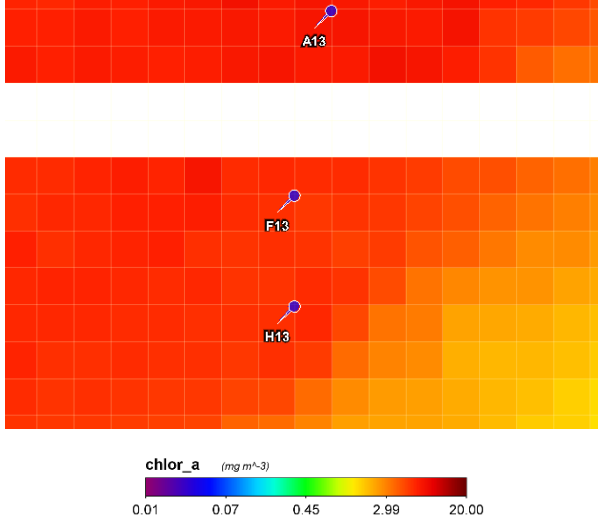


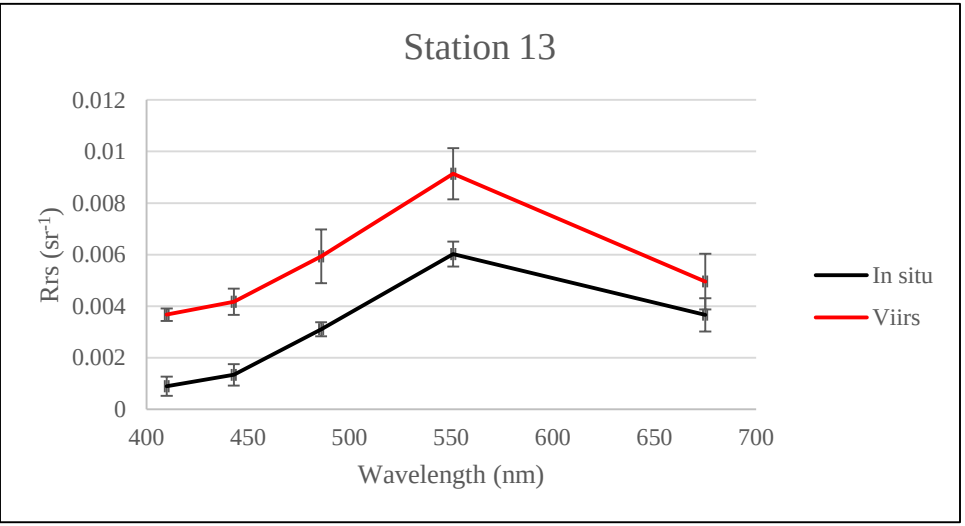
Percent difference relative to Average

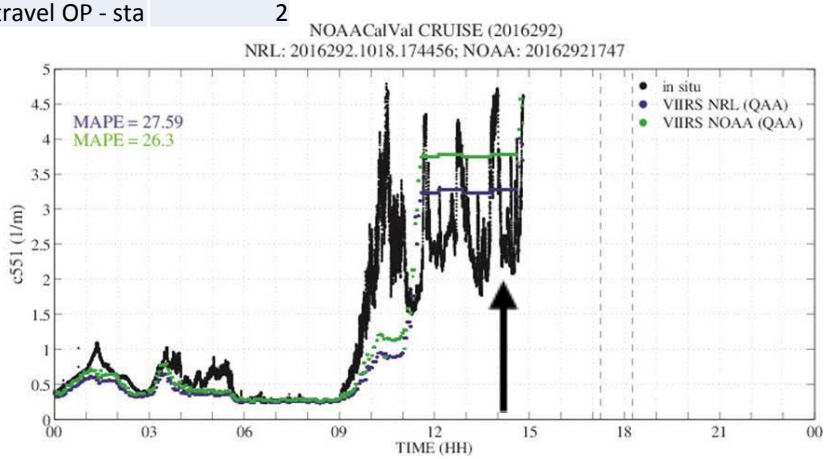
Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410	80.81	24.47	32.08	-8.57	6.53	5.24	3.80	-11.12	-8.65	-55.13	-13.19	-44.93	-11.32
443	72.37	25.14	31.84	-1.21	9.30	8.25	-1.07	-4.85	-13.23	-32.20	-24.69	-46.42	-23.22
486	62.37	25.13	27.19	4.53	12.72	10.85	-2.98	-2.09	-13.98	-16.86	-31.52	-44.96	-30.41
551	59.76	23.86	26.93	8.53	20.07	16.00	-2.70	-2.43	-19.74	-15.11	-34.57	-47.33	-33.26
675	128.60	21.59	31.41	7.42	41.22	42.94	-12.02	-10.95	-38.37	-42.04	-37.40	-103.77	-28.62



Date:	10/18, 292
Description:	Near shore, lots of mud
Overpass time:	1747
Above time:	1340
Surf. Time:	1420
Profile time:	1318
Depth (m):	14
Cloud cover (%):	0
Wind speed (kts):	4
Seas (ft)	1
Meas. Chl (mg/m^3)	2.5
VIIRS Chl (mg/m^3)	1.63
# pixels in 5 x 5	22
Current (m/s):	0.1
Current source direction:	315
Pixel travel OP - sta	2







Percent difference relative to Average

Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410	-81.75	27.84	-25.00	-16.90		50.94	32.79	39.59	-69.58	-79.98	74.08	-97.92	145.89
443	-48.37	68.69	-13.74	-10.48		17.76	-5.54	38.79	-22.64	-7.97	7.13	-65.86	42.24
486	-22.45	-3.22	-1.76	3.73		14.33	-7.76	35.79	6.15	15.63	-9.57	-39.98	9.11
551	-5.79	4.70	5.50	4.04		5.58	-7.04	28.86	10.35	24.13	-22.77	-34.20	-13.37
675	11.05	-7.67	52.21	-9.91		-12.31	3.82	55.34	-17.45	30.34	-35.91	-48.50	-20.99

Instrument Percent difference relative to average of all instruments

2014 VIIRS Validation Cruise

Band	Hyperpro	Hyperpro	Micropro	C-OPS	SBA	HyperTSRB	ASD	ASD	GER	HyperSAS
410	4.83	-0.41	1.93	-1.49	-9.01	-4.29	6.47	-1.82	4.04	-0.75
443	6.84	3.12	-0.35	-4.21	-8.90	-0.28	1.34	-3.30	6.19	-1.31
486	4.83	3.81	-0.37	-2.19	-9.86	1.01	-4.71	-2.21	10.38	-0.75
551	5.22	4.14	-1.86	-7.24	-9.12	5.52	-0.11	-4.75	8.53	-1.16
675	-9.18	-14.02	-14.91	-17.22	-8.57	36.15	38.47	0.24	5.46	-11.25
All	2.51	-0.67	-3.11	-6.47	-9.09	7.62	8.29	-2.37	6.92	-3.04

2015 VIIRS Validation Cruise

Band	Hyperpro	Hyperpro	Spec Evo	SBA	HTSRB 1	HTSRB 2	ASD 1	ASD 2	ASD 3	GER	HyperSAS
410	3.88	13.32	14.46	-1.04	-0.97	-1.68	-6.04	2.29	-12.15	-7.30	-17.42
443	4.97	10.15	10.09	0.48	-1.31	0.41	-10.97	-3.32	-12.94	-4.97	-4.86
486	6.45	9.93	4.84	1.37	-2.34	3.36	-15.05	-8.95	-14.12	1.09	0.92
551	7.39	3.18	6.46	-2.70	-2.06	6.48	-10.68	-2.11	-8.75	-5.98	-3.61
675	-5.43	-17.26	-3.61	-33.49	50.99	72.27	-5.04	9.29	-7.03	-44.38	-35.22
Average	3.45	3.86	6.45	-7.08	8.86	16.17	-9.56	-0.56	-11.00	-12.31	-12.04

2016 VIIRS Validation Cruise

Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410	6.80	7.56	17.28	-21.40	-8.72	-4.86	13.96	-16.20	12.09	-10.46	-2.70	-6.48	2.52
443	8.62	9.46	17.59	-10.49	-5.03	-1.72	9.17	-9.93	5.19	-6.61	-6.72	-8.32	-2.58
486	10.32	10.44	16.13	-4.61	-2.25	-0.31	6.16	-5.71	3.23	-4.06	-9.32	-9.91	-6.56
551	10.72	10.20	15.33	-3.37	2.38	3.61	5.84	-4.66	0.52	-7.57	-8.89	-11.63	-6.62
675	14.03	5.24	23.49	17.86	12.49	30.87	-2.98	-7.06	-7.12	-25.26	-3.56	-40.01	4.69
avg all	10.10	8.58	17.96	-4.40	-0.22	5.52	6.43	-8.71	2.78	-10.79	-6.24	-15.27	-1.71

MSL12 VIIRS Percent difference relative to in situ

2014 VIIRS Cal/Val Cruise

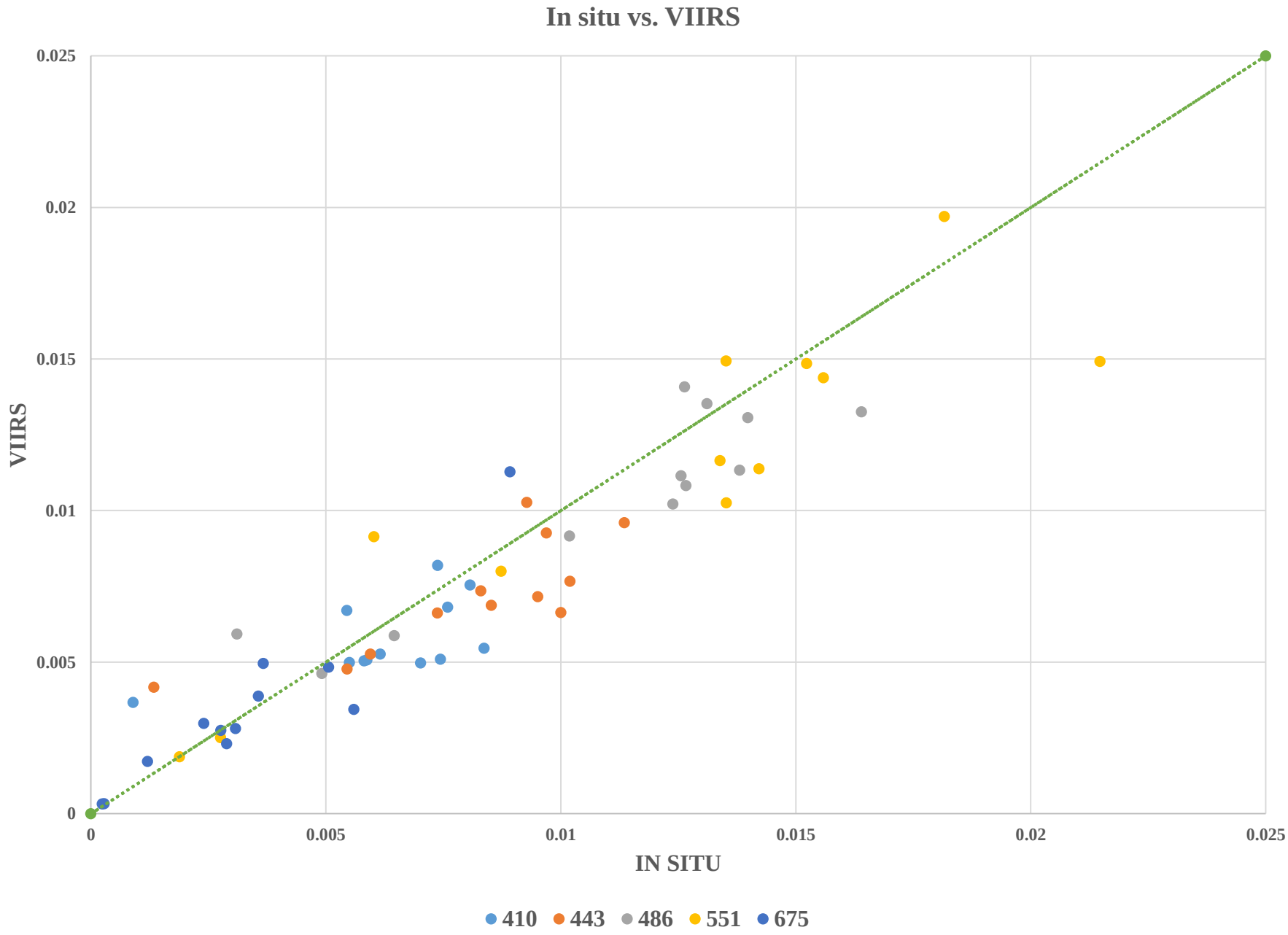
Band	Hyperpro	Hyperpro	Micropro	C-OPS	SBA	HyperTSRB	ASD	ASD	GER	HyperSAS	Average
410	-6.73	-3.36	-5.39	-2.15	10.31	1.57	-8.17	-8.73	3.33	3.85	**-3.79**
443	-13.15	-10.87	-7.45	-3.93	4.15	-7.42	-8.53	-9.38	-8.44	-3.90	**-8.31**
486	-6.49	-5.70	-1.44	0.45	11.28	-2.84	3.67	-2.83	-8.83	0.35	**-2.30**
551	-3.58	-2.71	4.05	10.21	14.65	-2.89	2.89	3.18	-2.82	5.52	**1.17**
675	-10.37	-0.44	1.06	1.70	-3.34	-28.45	-25.91	-9.02	-22.89	-4.94	**-17.04**
All	-8.07	-4.62	-1.83	1.26	7.41	-8.01	-7.21	-5.36	-7.93	0.18	**-6.05**

2015 VIIRS Cal/Val Cruise

Band	Hyperpro	Hyperpro	Spec Evo	SBA	HTSRB	HTSRB	ASD 1	ASD 2	ASD 3	GER	HyperSAS	Average
410	-10.71	-33.17	-32.44	0.69	-17.95	-2.30	-5.63	-13.05	-6.59	11.00	33.56	**-6.96**
443	-18.16	-31.21	-29.54	-8.79	-22.38	-11.47	-4.18	-11.97	-8.68	-4.17	-4.42	**-14.09**
486	-10.39	-19.94	-14.26	-0.97	-12.37	-5.97	13.50	4.83	4.68	-2.64	-2.58	**-4.19**
551	-20.75	-24.85	-24.76	-7.82	-24.11	-18.53	-0.83	-12.52	-11.21	-6.12	-7.59	**-14.46**
675	-5.97	-7.69	1.95	82.36	-45.75	-40.02	0.21	-15.49	-9.78	82.26	56.15	**8.93**
Average	-13.20	-23.37	-19.81	13.09	-24.51	-15.66	0.62	-9.64	-6.32	16.07	15.02	**-6.16**

2016 VIIRS Cal/Val Cruise

Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSA	ASD 1	ASD 2	ASD 3	ASD 4	Average
410	-21.14	-13.021	-14.58	-8.6991	-10.169	-5.1651	-17.349	9.41287	-13.086	-9.5444	-13.751	-15.726	-14.526	-11.33
443	-23.637	-18.248	-16.385	-9.1118	-12.199	-9.3288	-13.487	-6.5252	-10.053	-9.5982	-6.3806	-4.6875	-12.335	-11.6
486	-19.977	-19.423	-10.79	-8.2182	-5.8882	-8.393	-12.214	-8.6991	-9.2464	-3.9016	-0.0429	-8.7008	-4.4225	-9.224
551	-20.499	-16.072	-14.42	-5.4567	-10.169	-12.975	-13.573	-4.5217	-7.5895	-5.0782	-7.3789	0.5504	-1.7808	-9.150
675	-9.0381	23.9794	8.34418	8.53912	6.38464	-10.026	10.6155	13.2666	12.936	30.5061	10.9994	18.1037	0.3017	9.6085
avg all	-18.858	-8.5568	-9.5662	-4.5893	-6.4082	-9.1776	-9.2014	0.58669	-5.4078	0.47673	-3.3107	-2.0921	-6.5525	-6.358


In situ vs. VIIRS
0.025
0.02
0.015
0.01
0.005
0
VIIRS
0
0.005
0.01
0.015
0.02
0.025
IN SITU
410
443
486
551
675

Summary:

Despite Hurricane, we were able to conduct several good validation stations while optically characterizing the aftermath of a hurricane path.

Variability between in situ measurements in coastal waters is dominated by inter-pixel variability despite some biases between measurements.

10 to 20% variation between independent in situ measurements in coastal waters. Simultaneous measurements with identical, inter-calibrated instruments and identical processing greatly reduces the variability.

VIIRS is slightly under-estimating radiances in coastal water relative to shipboard measurements.

Session 7

2017 STAR JPSS Annual Science Team Meeting,
College Park, Maryland
August 16, 2017

Evaluation of VIIRS Ocean Color products and development of enhanced ocean products and applications

Robert Arnone[1], Sherwin Ladner[2],Bill Gibson[3] , Wes Goode[2],

1- University of Southern MS 2. Naval Research Laboratory 3. La State University

Topics:

1. Cal Val Foster Cruise – 2016 Mathew – Summary
- **Matchups , HyperPro / ASD**
- **Protocols**
- **Flowthrough → also Poster- Ladner, Arnone, Goode, Anderson**

2. Diurnal VIIRS Paper - VIIRS products using difference fields
- **Importance of matchup time for cal –validation -)Seasonal changes in color**

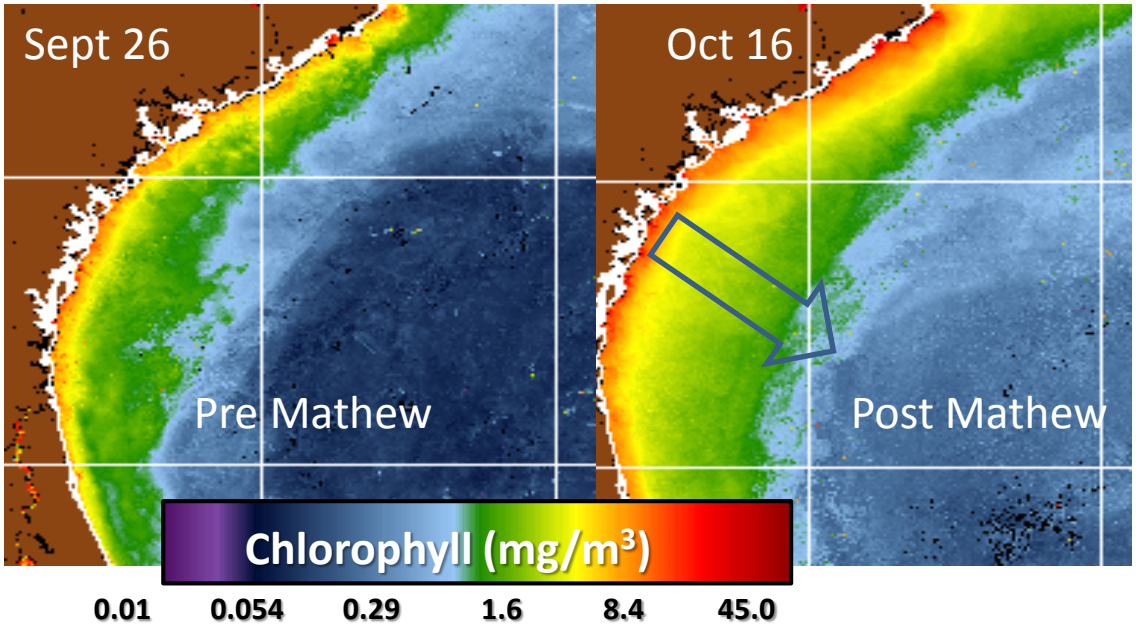
3. Anomaly products (VIIRS and Models) - Events - Hotspots SPIE paper
- **Applied to Blue Fin Tuna Foster → Poster –Arnone, Jones, Soto**

4. WavCIS Aeronet Status

5. Invitation SPIE -Ocean Sensing and Monitoring April 15-19

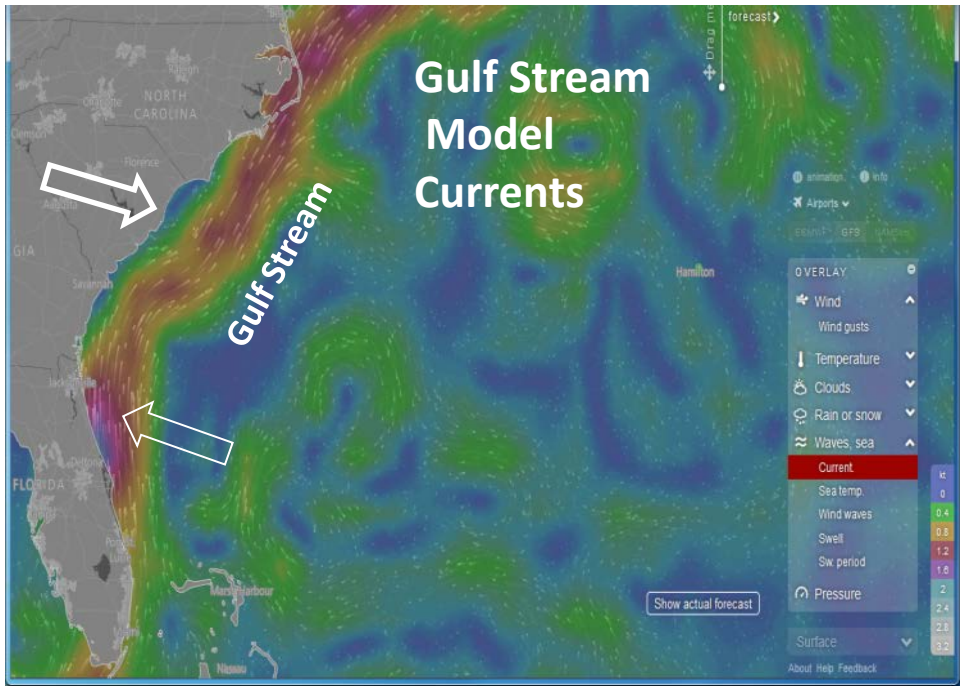
Stennis - Cal val Team Annual Summary

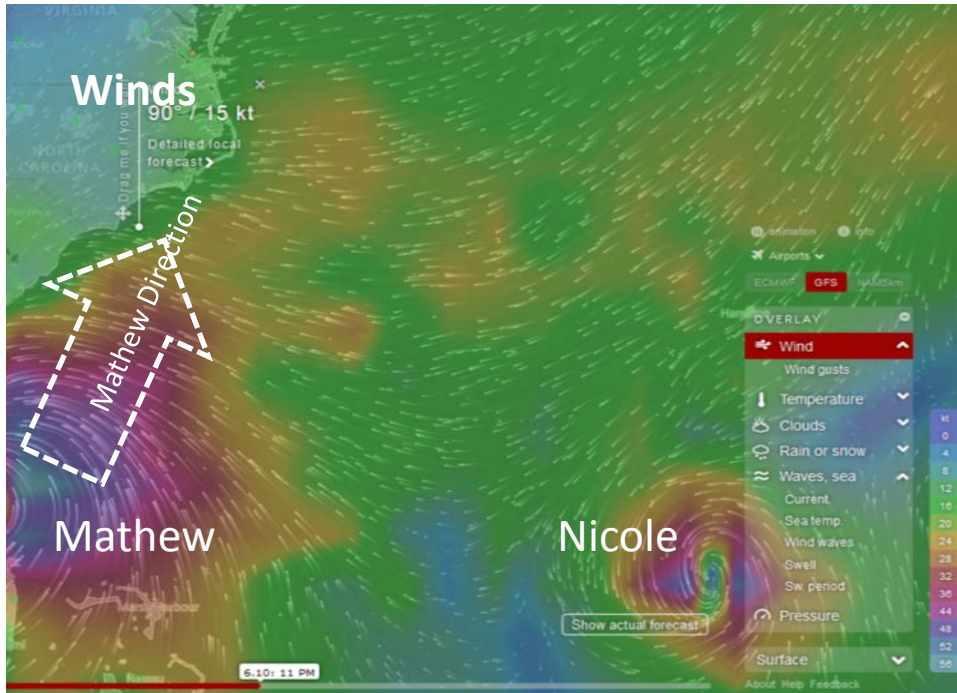
Influence of Hurricane Mathew on the Coastal waters



Foster Oct 2016 Cruise

1. Chl Extended offshore
2. Movement of the Gulf Stream onto the coast areas
   SST didn't detect Stream with uniform Temperature.
3. Exchange of Coast waters offshore Discharge
4. Cruise departed 5 days following Passage of Mathew

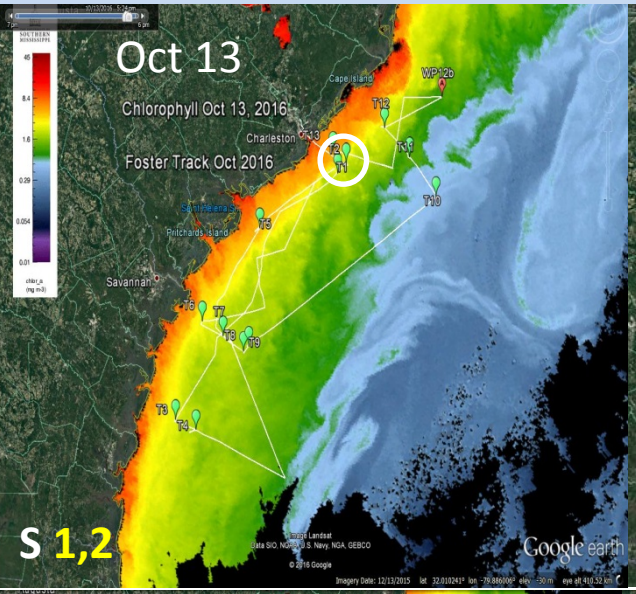


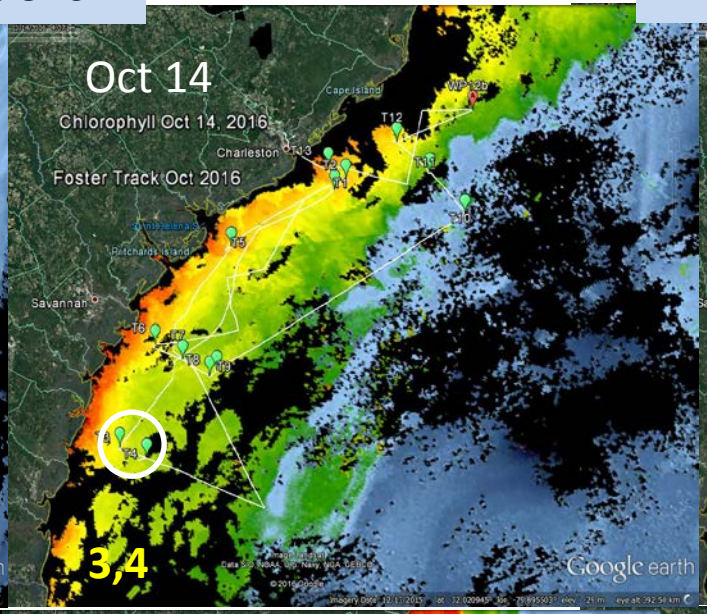


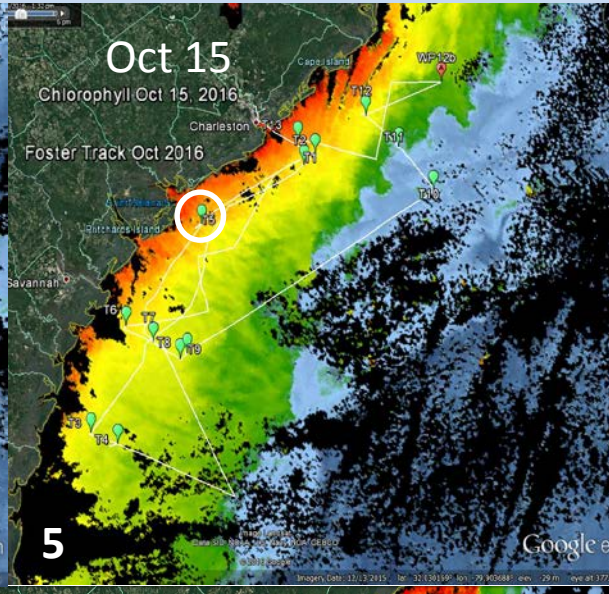
Cal Val cruise 2016 - Foster - Flowthrough – IOP

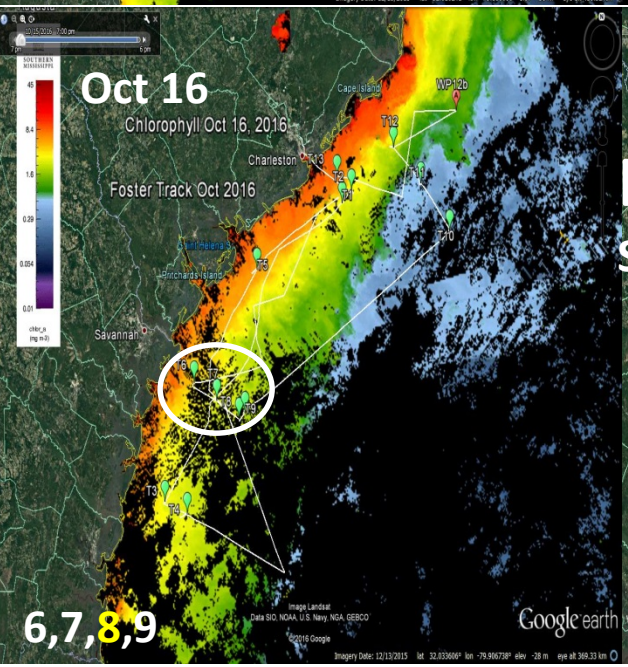
VIIRS Daily Coverage with Stations

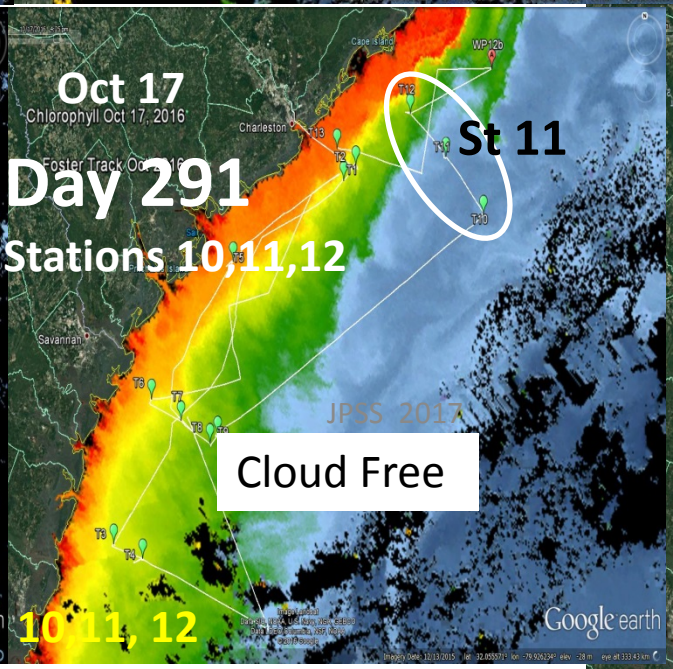
Foster Stations Oct 2016

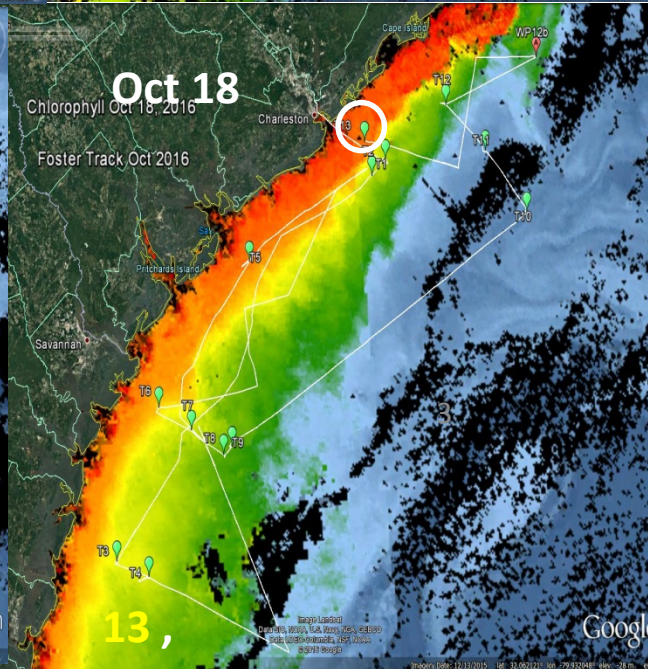












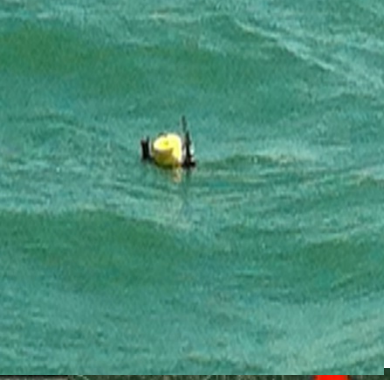
FOSTER 2016 Cal Val cruise

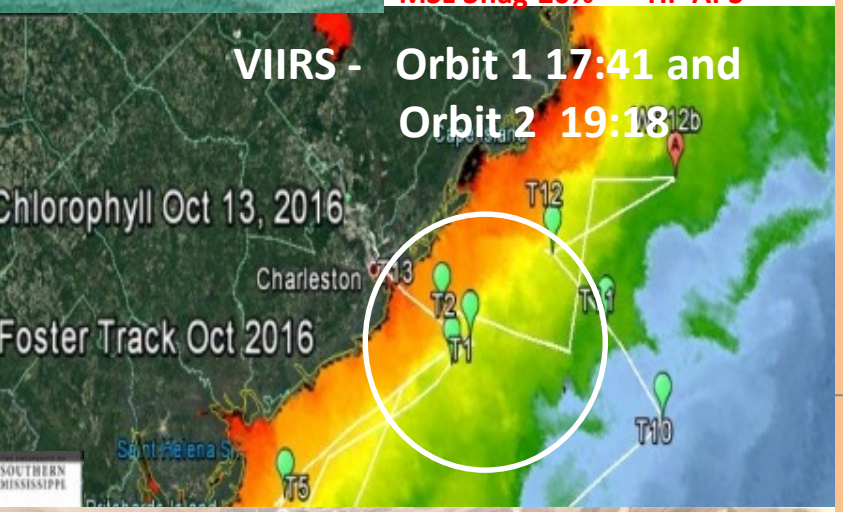
Oct 13, 2016

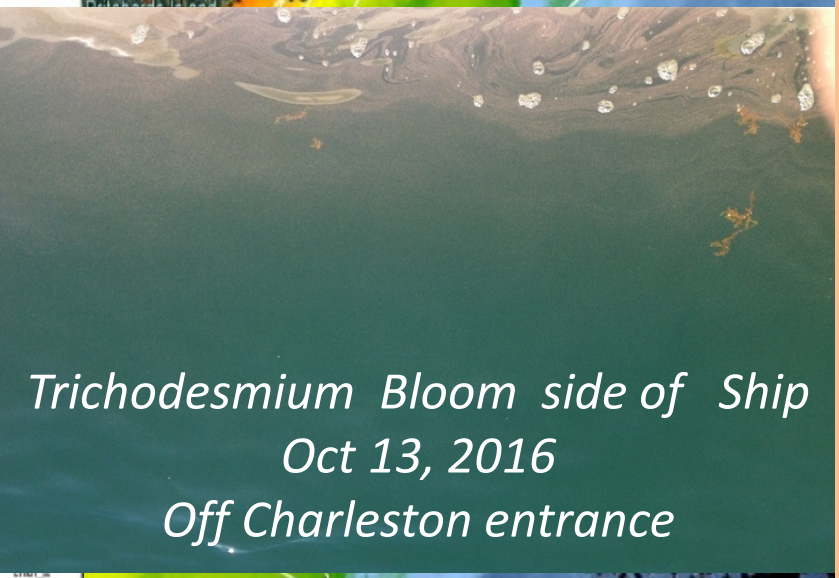
← 2 Floating Hyperpros

- Hyperpro – NOAA
- VIIRS Matchup- revised
- 1x1 APS (5x5)

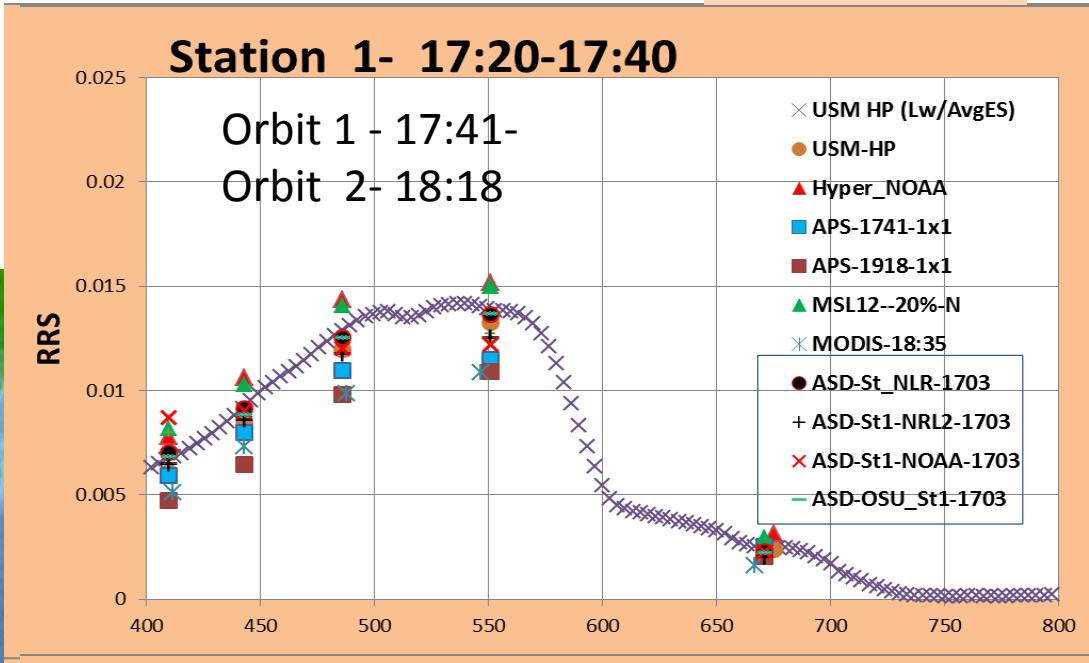
MSL 3flag-20% - HP APS

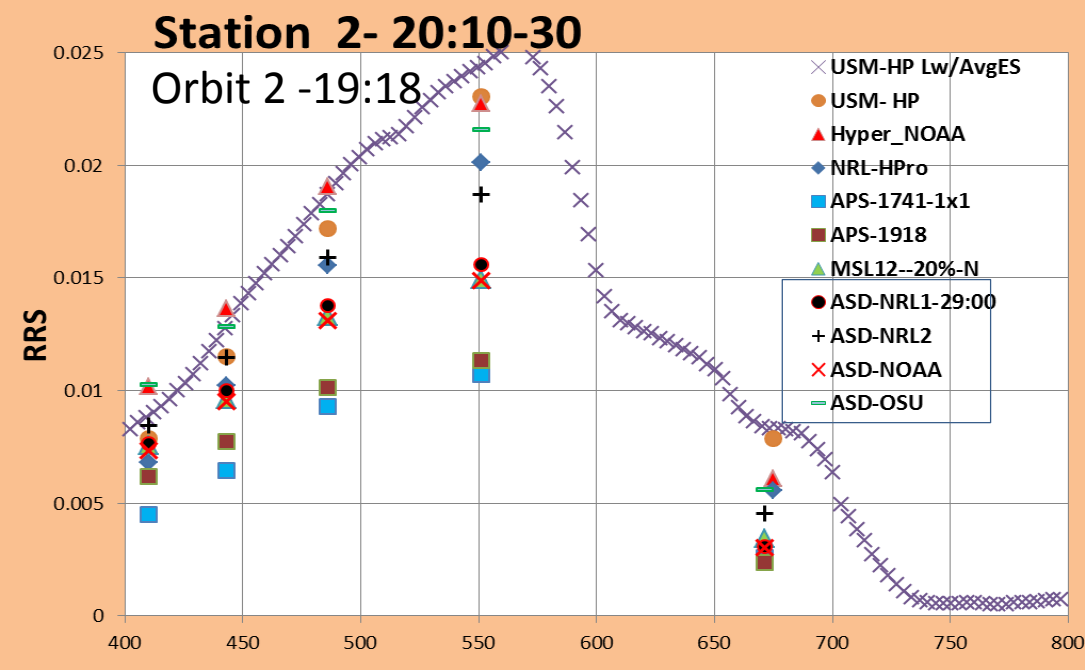






Plus 4 ASD



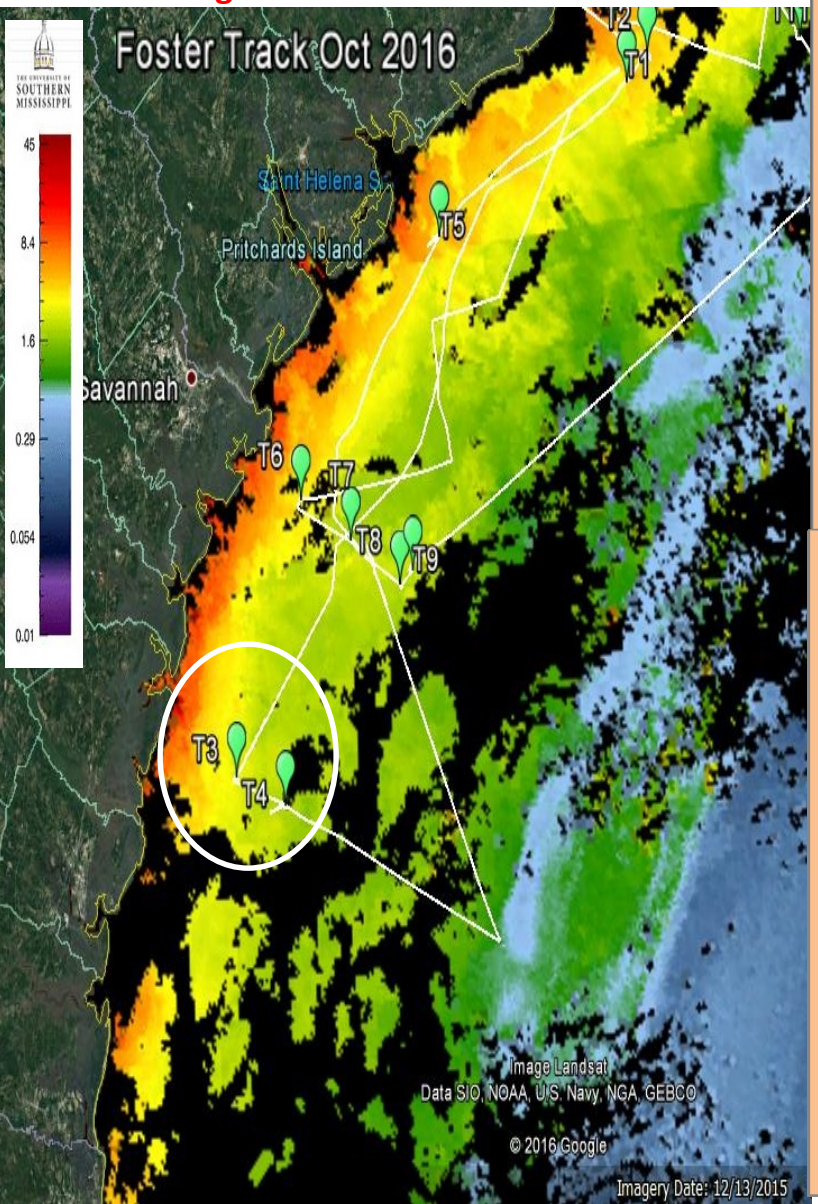


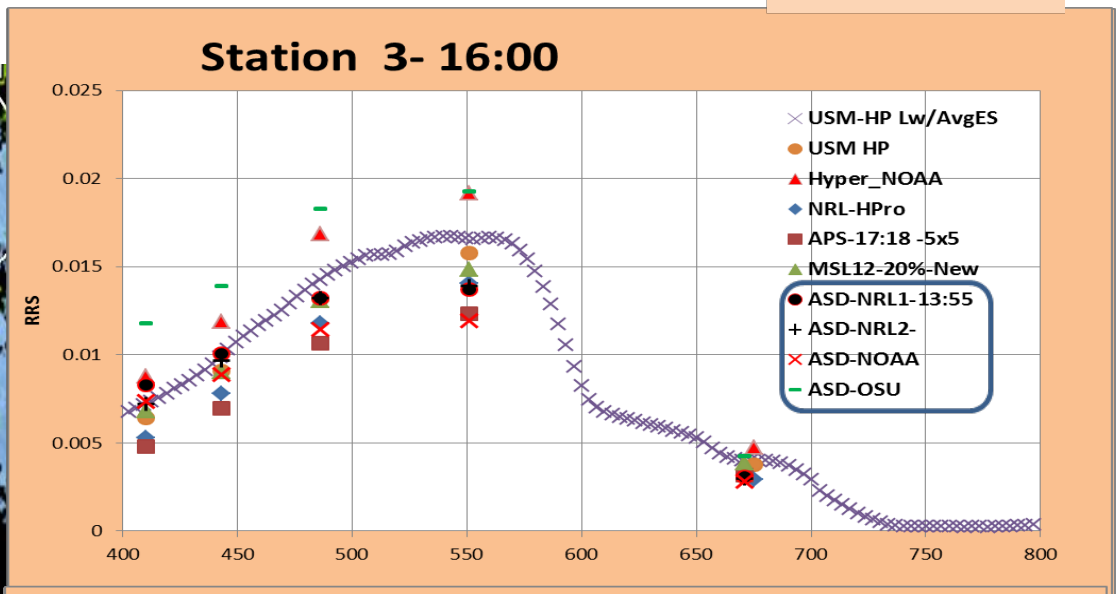
FOSTER 2016 Cal Val cruise Oct 14, 2016

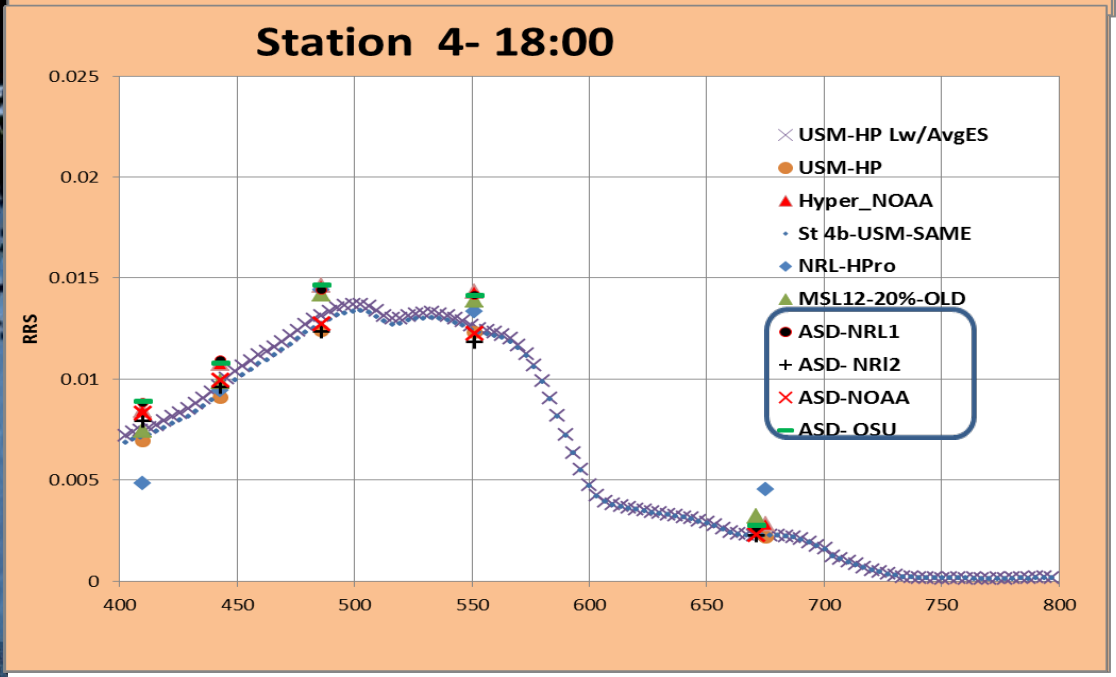
- Floating Hyperpros (USM- NRL)
- Hyperpro – NOAA
- MSL 3flag-20% - HP-APS

VIIRS Overpass – 17:18

Plus 4 ASD





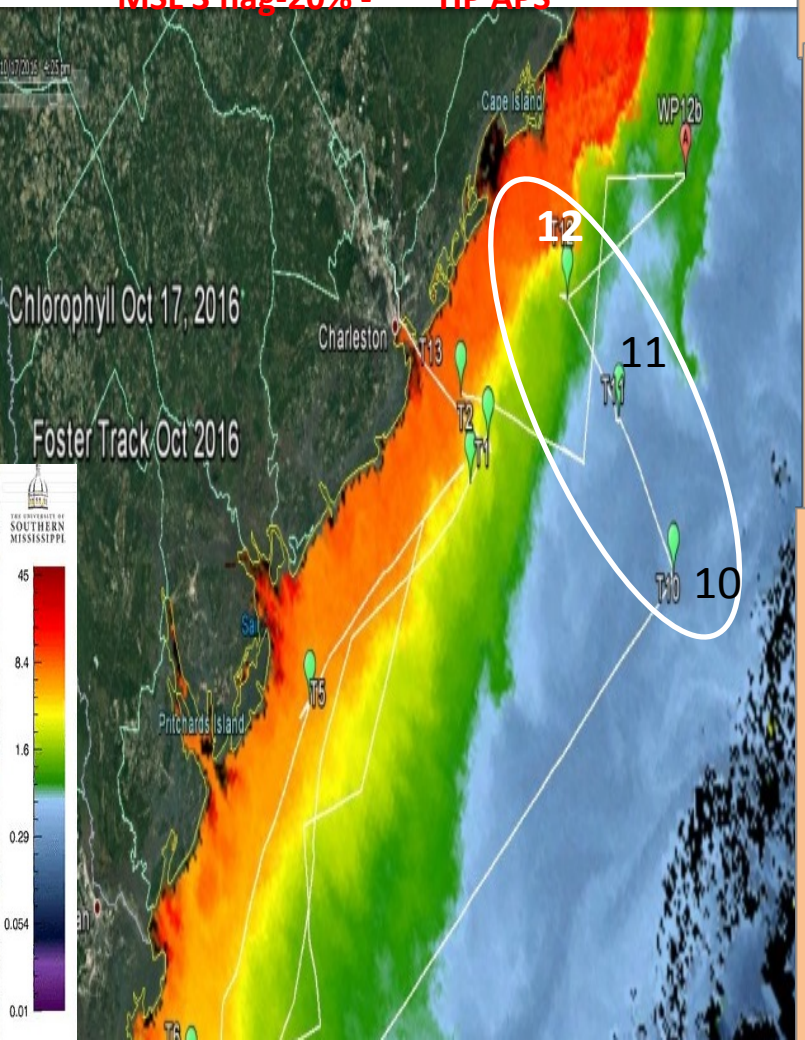


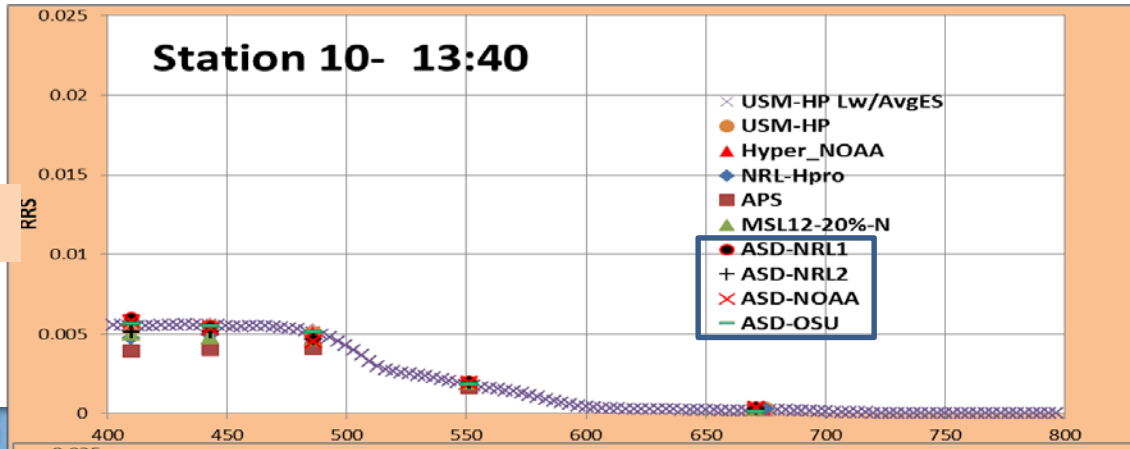
FOSTER 2016 Cal Val cruise Oct 17, 2017

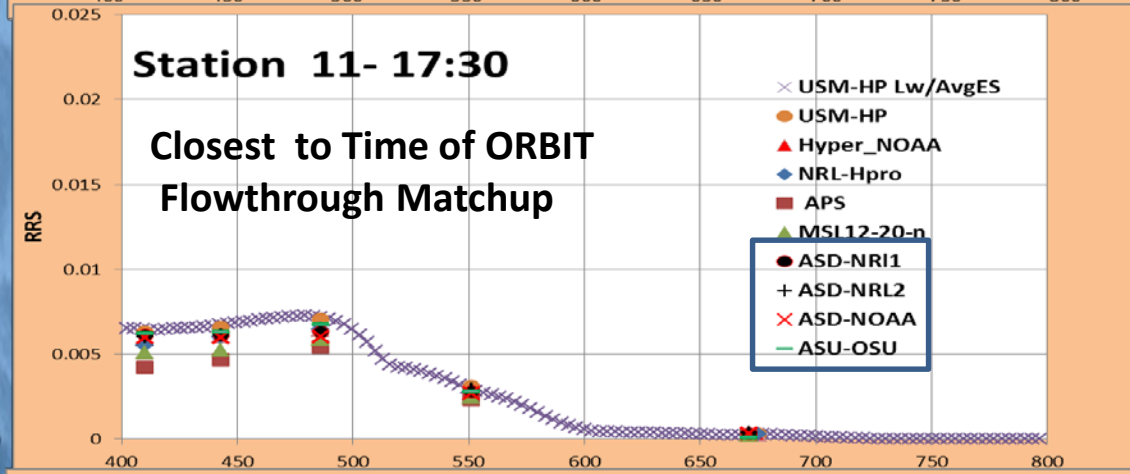
- Floating Hyperpros (USM- NRL
- Hyperpro – NOAA
- St 11 is Closest Matchup at time of Orbit – 18:02

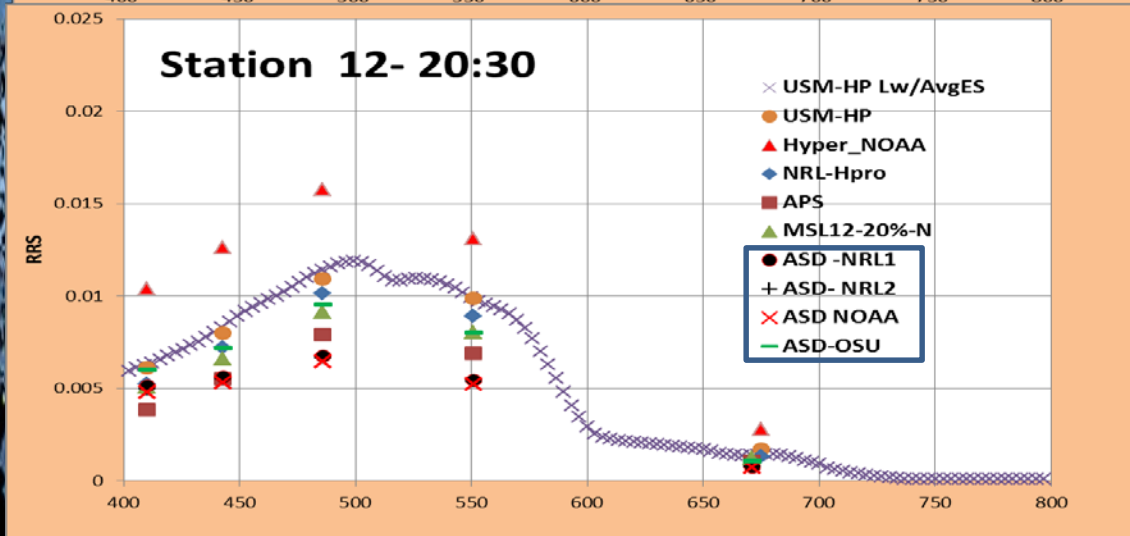
Plus 4 ASD

MSL 3 flag-20% - HP APS



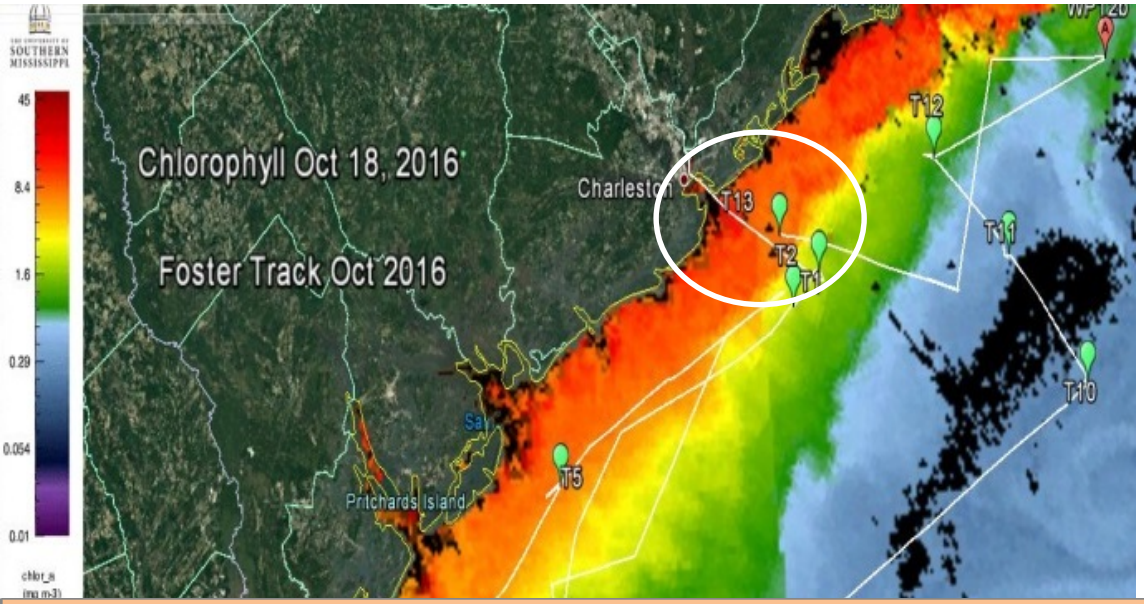




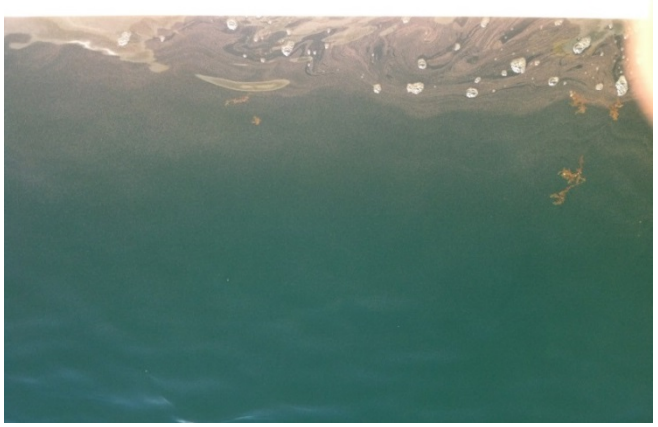


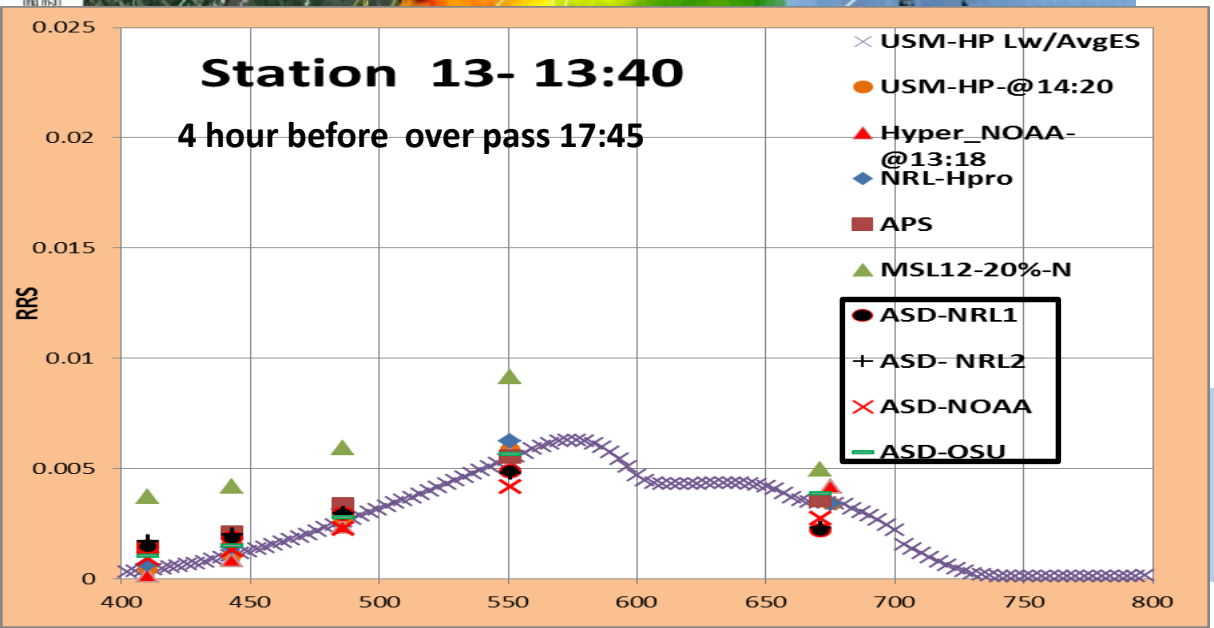
FOSTER 2016 Cal Val cruise

Foster Oct 18-- Orbit at 17:45



The surface Waters were scattered *Trichodesmium Bloom Off side of Ship.*





Plus 4 ASD

3 Hyperpros agreed at Stations

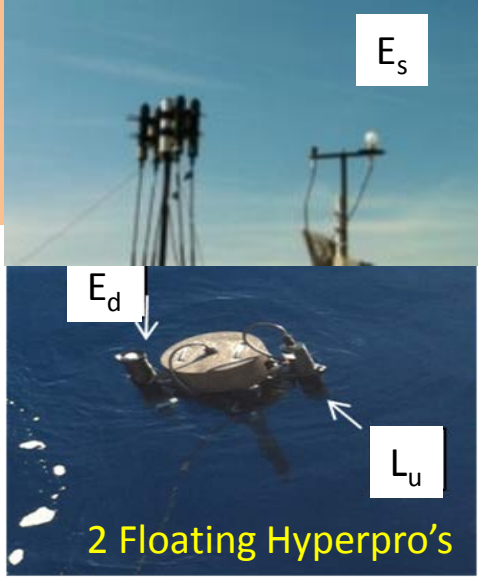
Coastal waters surface Patches

MSL 3 flag-20% - HP APS

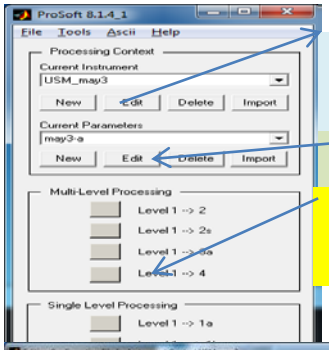
: Established Floating HyperPro Protocols for using Prosoft software for processing.

Floating Hyperpro Protocols

for Post Processing - Prosoft 8.1.4.



1. **Measurements were made over 10 minute time period.**
2. **Processing using Prosoft v8.1.3-4 and data were averaged over the deployment interval and tilts greater than 2 degrees was omitted.**
3. **Use the Es rather that ED (tested both)**
4. **Did a consistency of ALL ES sensors on Foster !**
5. **Fresnel reflectance (*p*) = 0.025 and refractive index of sea water (*n*) = 1.34 (Prosoft Defaults). factor = (1-0.021)/(1.345^2); Rrs = L_u*factor/$E_{d,s}$**



Steps

#1 Edit and load the cal

-

#2 - Edit to set up parameters

#3 process.

level 1→ Level 4

Set ups

```
PROFILER : WET
REFERENCE : OFF
PRO-DARK : OFF
REF-DARK : OFF
PRO-ID : MPR0093
PROCESSING_LEVEL : 4
FILE_CREATION_TIME : 11-Mar-2016 17:27:47
DEGLITCH_PRODAT : OFF
DEGLITCH_REFDAT : OFF
STRAY_LIGHT_CORRECT : OFF
THERMAL_RESPONSIVITY_CORRECT : OFF
DEPTH_RESOLUTION : 0.01 m
BIN_INTERVAL : 0.05 m
BIN_WIDTH : 0.1 m
TIME_INTERVAL : 2 sec
TIME_WIDTH : 1 sec
WAVEL_INTERP : 0 nm
INTEGRATION_POINTS : 5
REFLECTION_ALBEDO : 0.043
REFLECTANCE_INDEX : 0.021
REFRACTIVE_INDEX : 1.345
ET_SOLAR_SPECTRUM : Thuillier
WATER_MEDIUM : sea water
LS_DISTANCE_SURF : 0.2
```

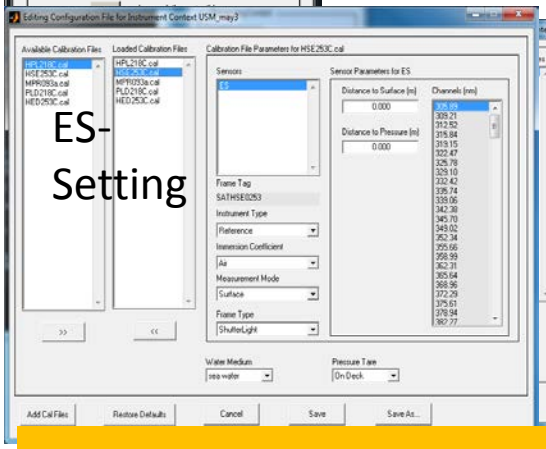
$$L_w(\lambda) = \frac{1-\rho}{n^2} L_u(0^-, \lambda)$$

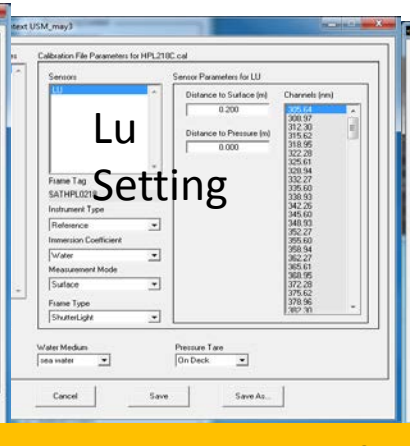
ρ = 0.025 is the Fresnel reflectance of the air sea interface,

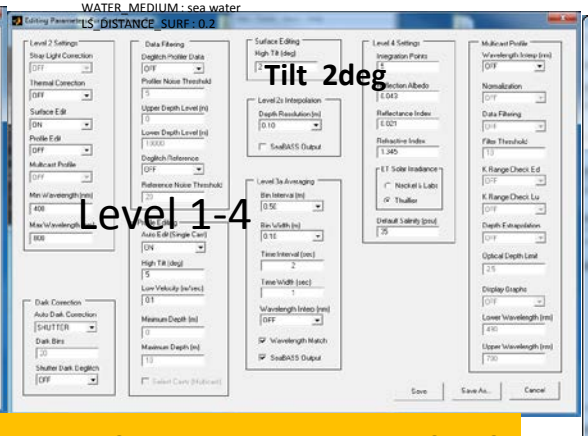
n = 1.34 is the refractive index of seawater.

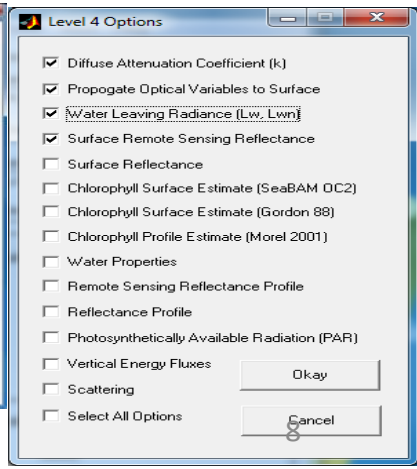
Remote sensing reflectance

$$R_{RS}(\lambda) = \frac{L_w(\lambda)}{E_S(\lambda)}$$







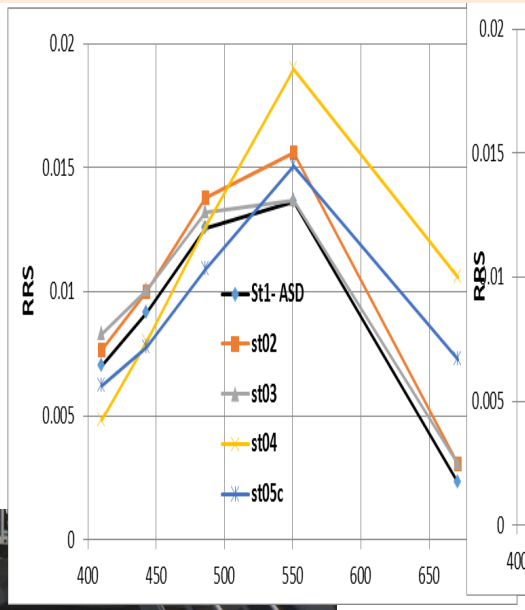


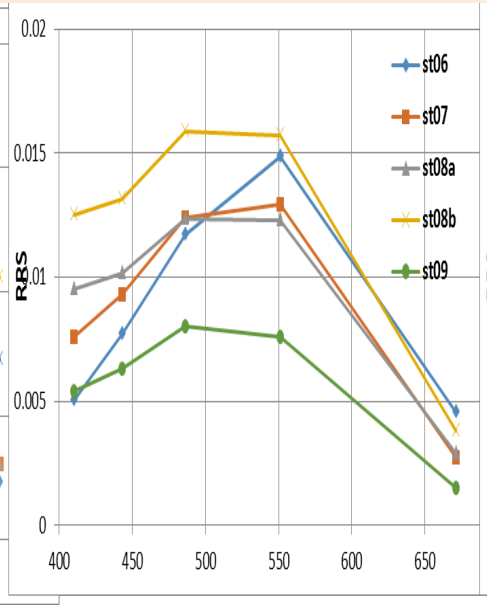
1. Consistent Between Sensors 2. Similar results using ES and Ed

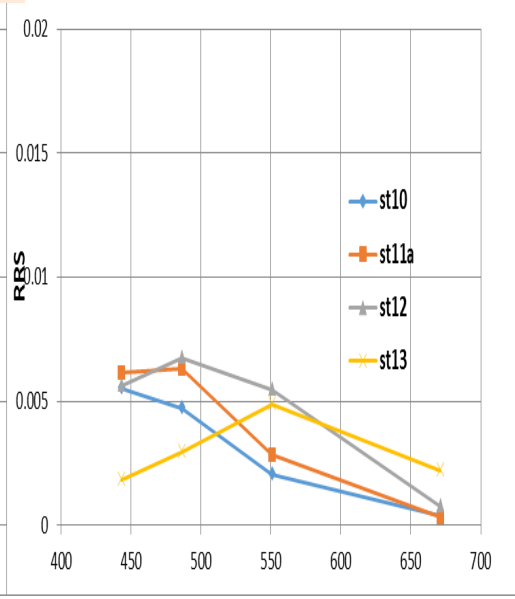
Above water – ASD for Stations and Blue tile

Addressing ASD protocols

ASD –
St – 1,2,3,4
5,6,7,8a,b,9
10,11,12,13,

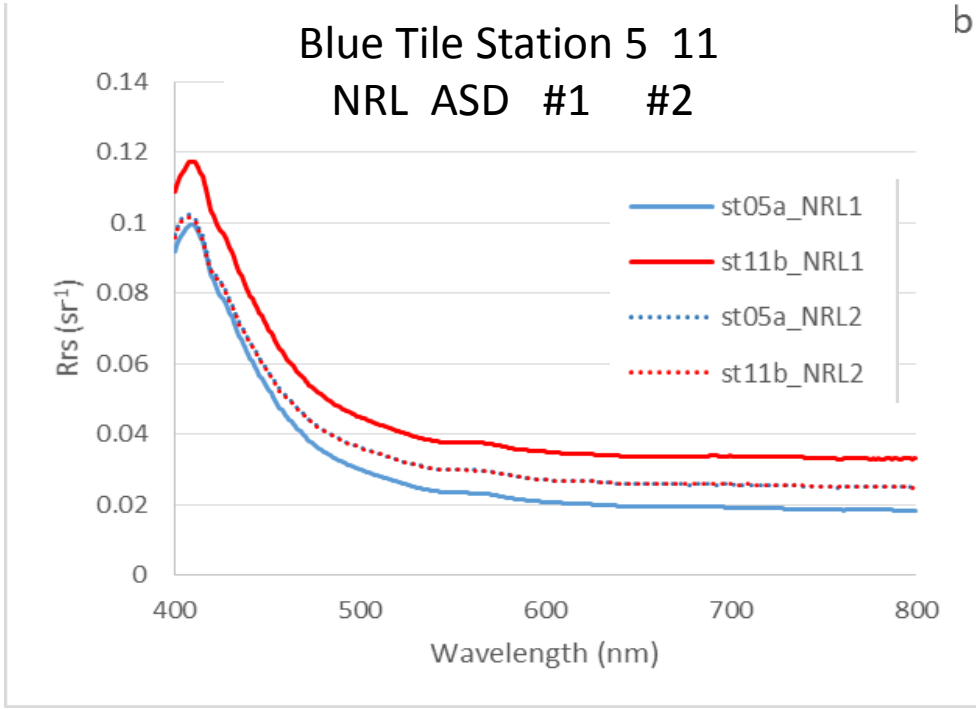




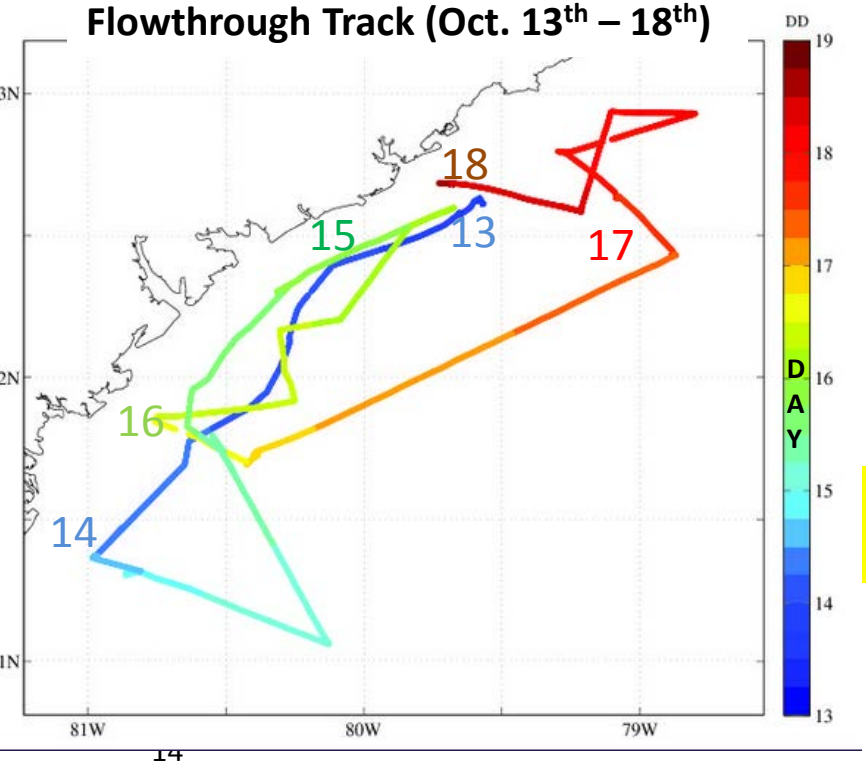




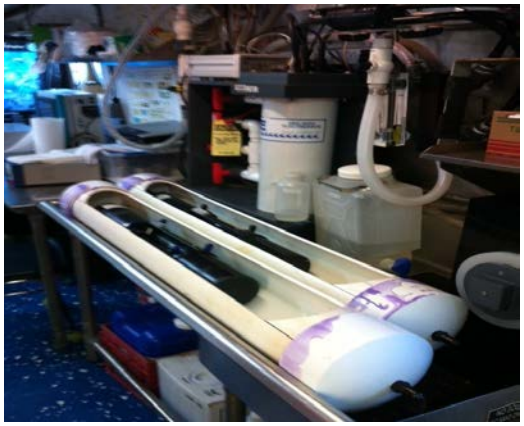
- 2 blue tile stations for 2 NRL ASDs (1,2) for 2 stations (5a,11b).
  - #2 - Consistent at both
  - #1 - Changed



Foster 2016 Flowthrough → absorption (Acs), backscattering bb



Spectral Absorption and Scattering IOP



Acs Filtered and Unfiltered

A. Validate VIIRS Inherent Optical Properties Spectral total absorption → at 410,443, 486, 551,671

B. Continuous underwater measurements from flowthrough defined the spatial optical variability at stations.

C. How did the optics change within a VIIRS Pixel? Needed for pixel calibration !

D. Identified the Spatial variability at the time of Overpass

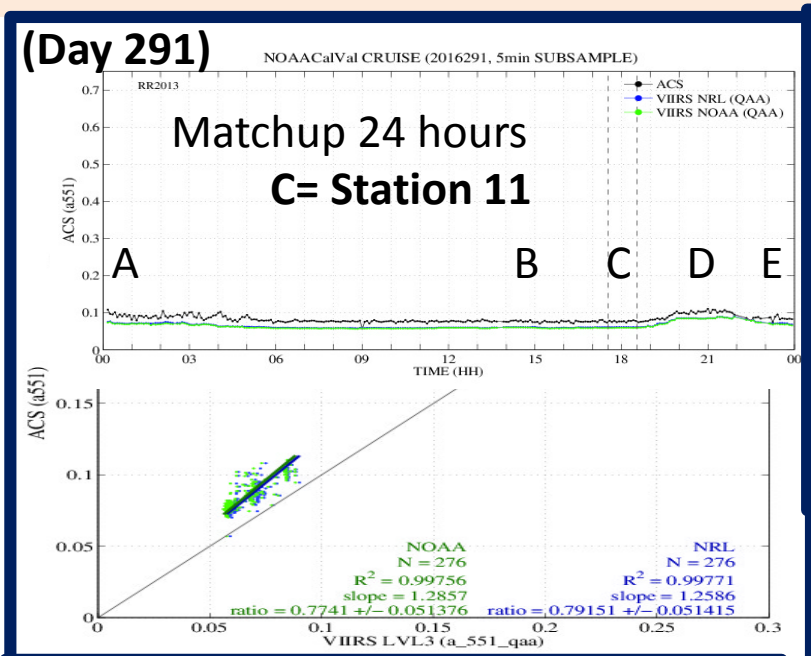
E. Established protocols for acs – Scattering Comparison of Scatter Correction : using Rudiger RR -

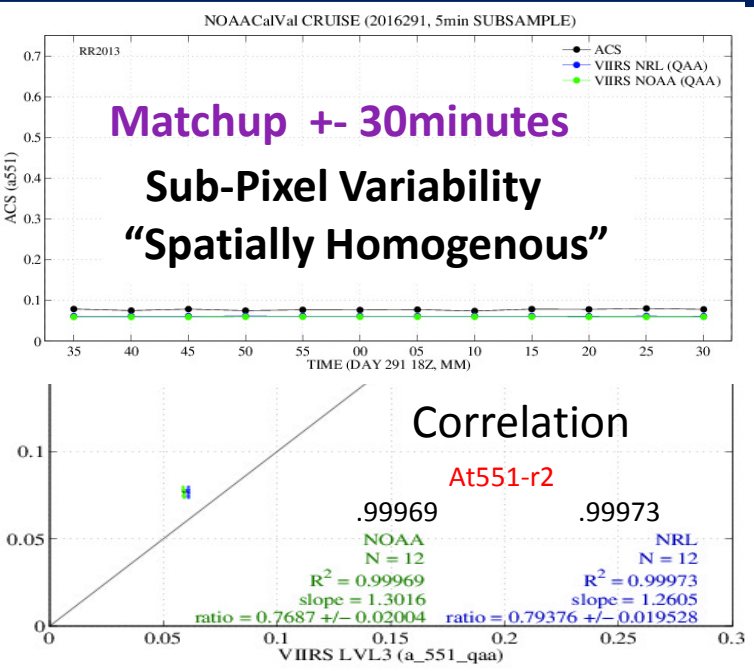
F. VIIRS Validation Matchup done for the 24 hour Day and +- 30 minutes of overpass.

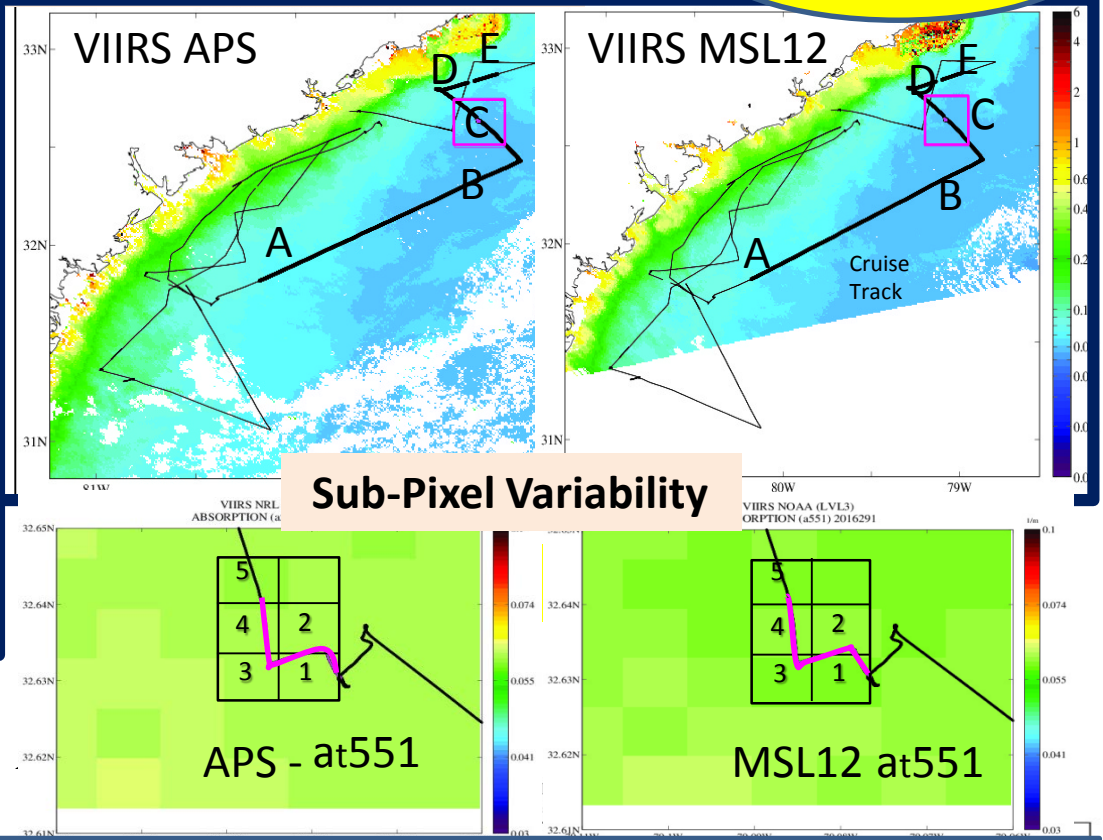
Poster - Evaluation of SNPP VIIRS Inherent Optical Properties during the 2016 NOAA Cal/Val Cruise – Ladner, Arnone, Goode, Anderson

Mar 17,2016 Flowthrough Total Absorption at 551

(Day 291)







Station 11 - Excellent Matchup- Spatially Consistent

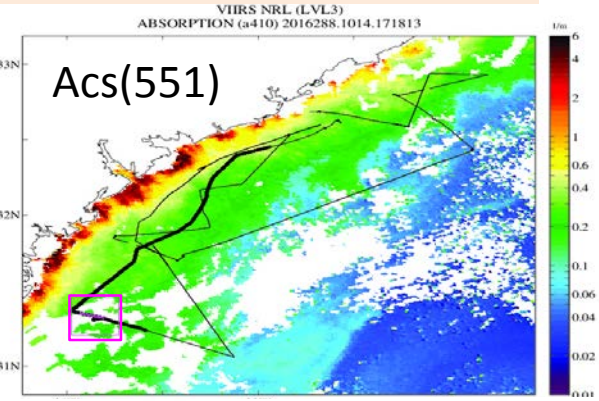
+- 30minutes

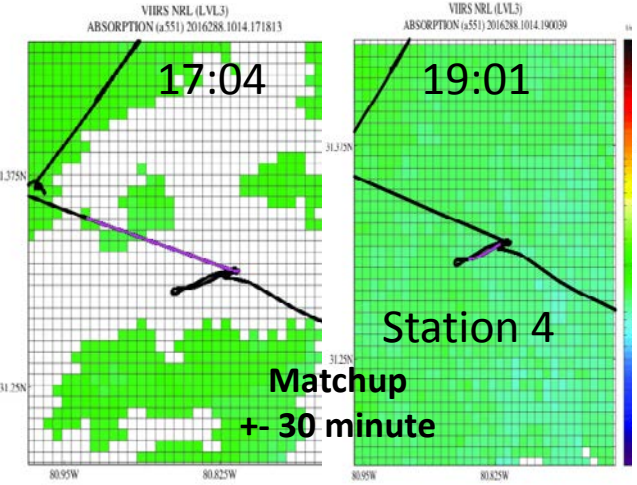
Station 11 VIIRS-Total Absorption R_2

	MSL12	APS
410	.99724	.99744
443	.99768	.99839
486	.99869	.99915
551	.99969	.99973
671	.99992	1.0

Foster 2016 Matchup Flowthrough IOP absorption

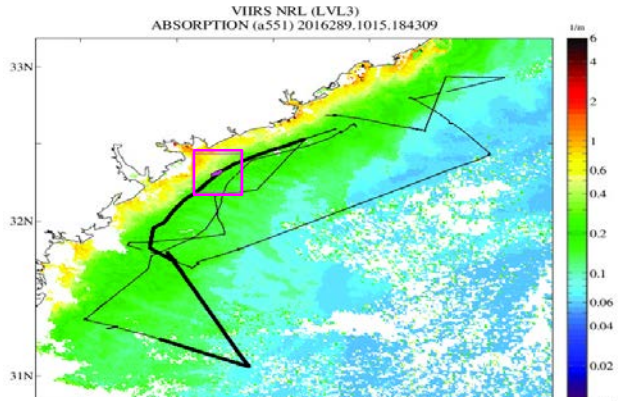
Day 288 - Oct 14 , 2017

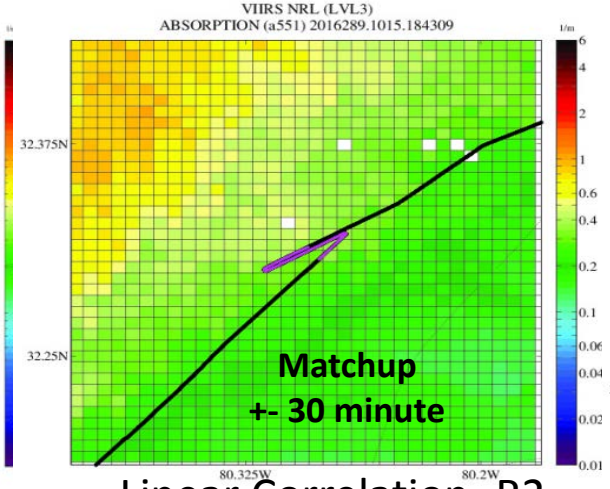




Total Absorption 551 St4		
Day 288 St 4 Oct 14		
	APS R2	
	17:04	19:01
410	.99744	.99829
443	.99883	.999
486	.99987	.9994
551	.99985	.99963
671	.99995	.99997

Day 289- Oct 15, 2017

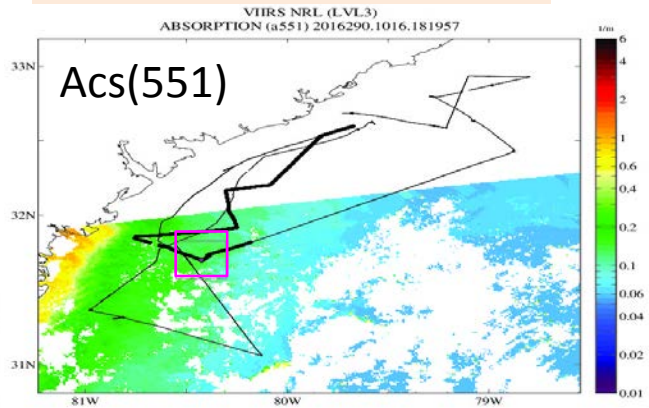


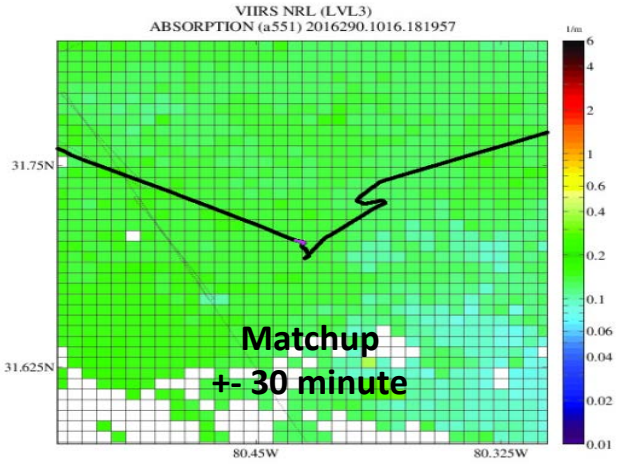


Linear Correlation- R2

Total Absorption 551 – St 5		
Day 289 18:42 Oct 15 R2		
	MSL12	APS 17:06
410	NA	.98689
443	NA	.98587
486	NA	.98526
551	NA	.98458
671	NA	.99497

Day 290- Oct 16, 2017

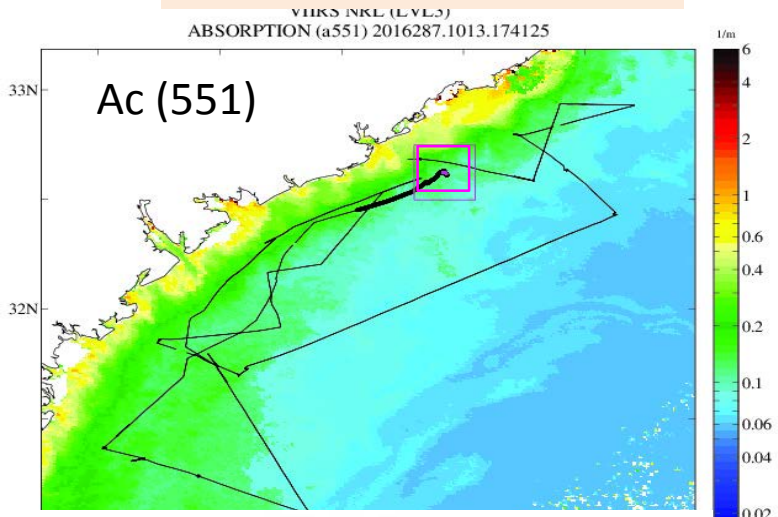


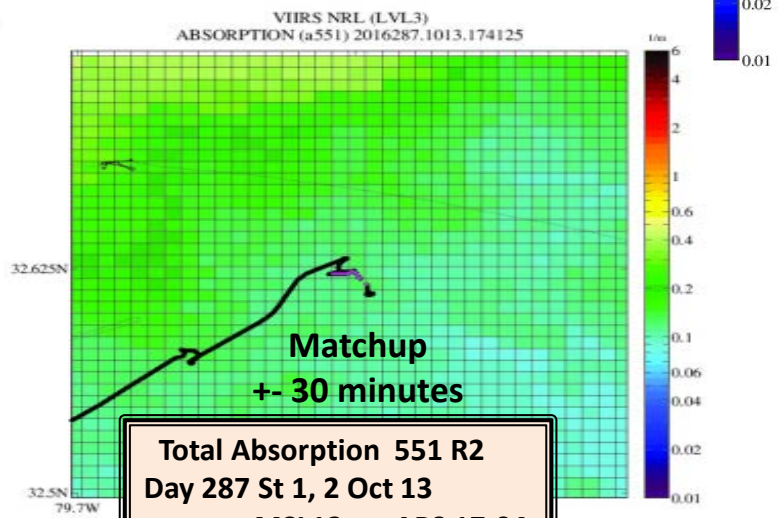


Total Absorption 551 –St 9		
Day 290 - Oct 16 R2		
	APS 19:01	MSL12
410	.99568	clouds
443	.99614	
486	.99602	
551	.99729	
671	.99979	

Foster 2016 Matchup Flowthrough IOP absorption

Oct 13 , Day 287 First

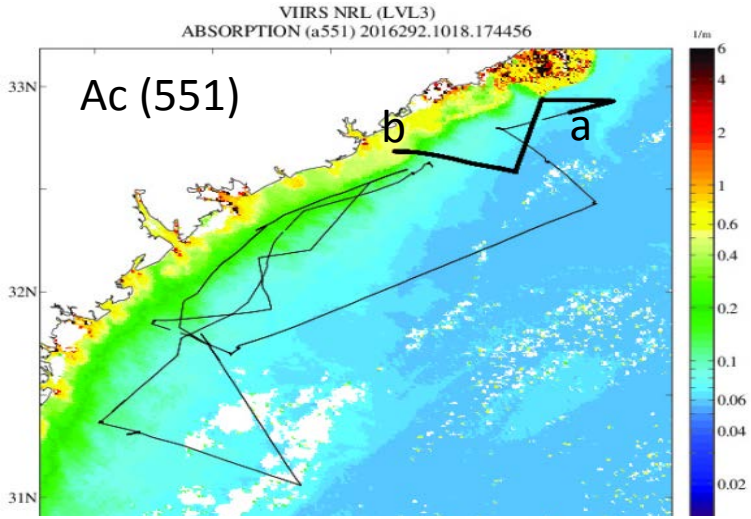




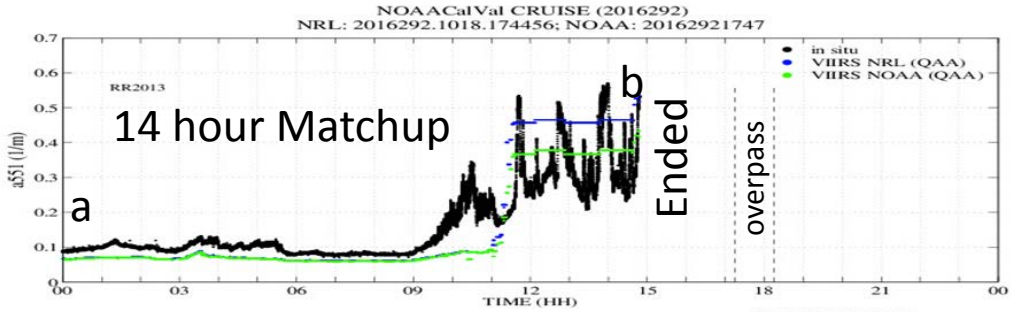
Total Absorption 551 R2
Day 287 St 1, 2 Oct 13

	MSL12	APS 17:04
410	.99994	.99889
443	.99994	.99912
486	.99991	.9916
551	.99991	.99923
671	1.0	.99996

Oct 18 , Day 292 Last

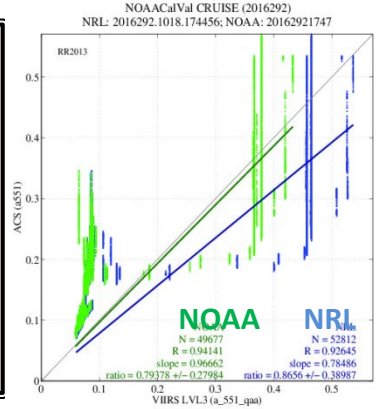


No matchup at Time of Orbit



Total Absorption 551 R2
Day 292 Oct 18 17:47
total 14 hours prior

	MSL12	APS
410	.93352	.93895
443	.94208	.93185
486	.93405	.92439
551	.94141	.92645
671	.94235	.93352



Enhanced Potential VIIRS

New VIIRS – Orbital Overlap
Valid Data
Diurnal Changes in ocean color
~ 100 minutes

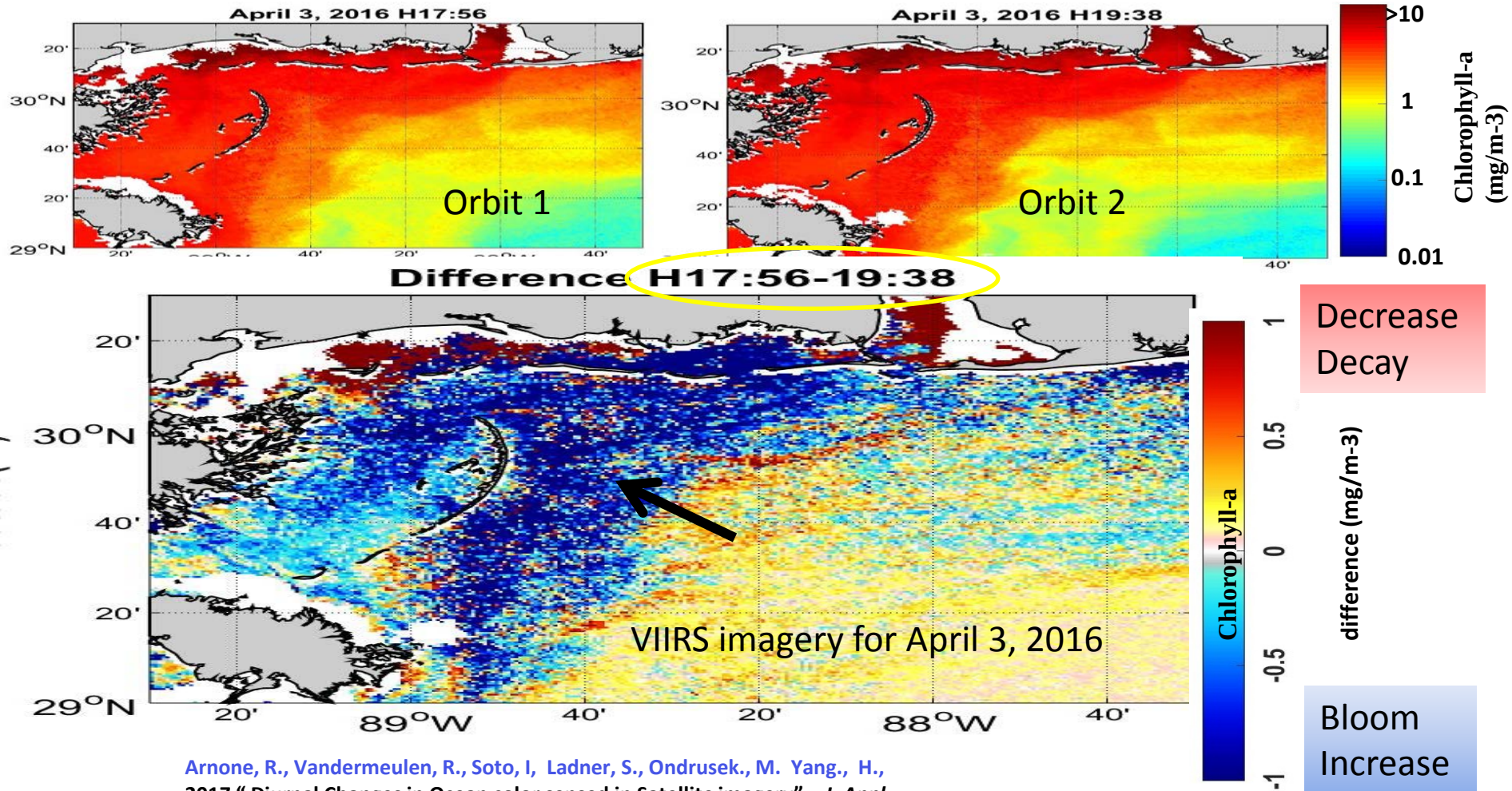
Can affect the Matchup time

Enhanced Products Diurnal Changes from VIIRS Orbital Overlap

What Can Cause Diurnal Color change ?

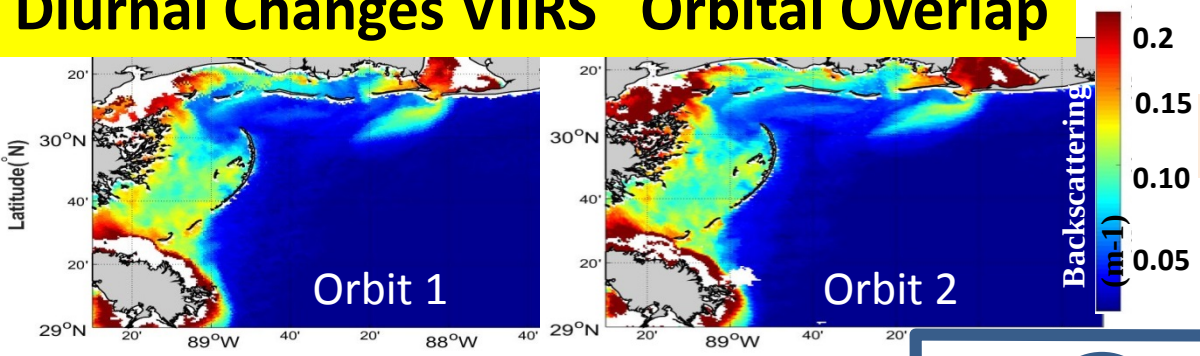
New - VIIRS Difference Products

1- Advection of Water masses - Estimate the surface "currents" →(Max Cross Correlation)
2- Biological Bloom or Decay , Particle Resuspension
3- Vertical Movement of optical layers - Upwelling and Downwelling
- Phytoplankton Migration (HAB detection during the day)



Arnone, R., Vandermeulen, R., Soto, I, Ladner, S., Ondrusek., M. Yang., H., 2017 " Diurnal Changes in Ocean color sensed in Satellite imagery", *J. Appl. Remote Sens*. 11(3), 032406 (May 09, 2017). doi:10.1117/1.JRS.11.032406

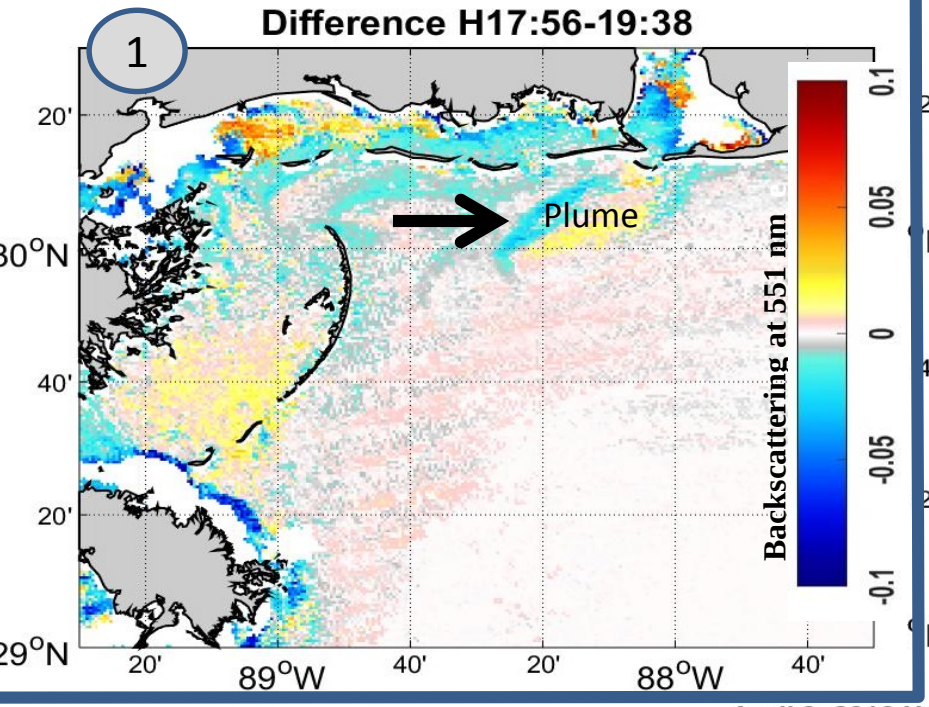
Diurnal Changes VIIRS Orbital Overlap

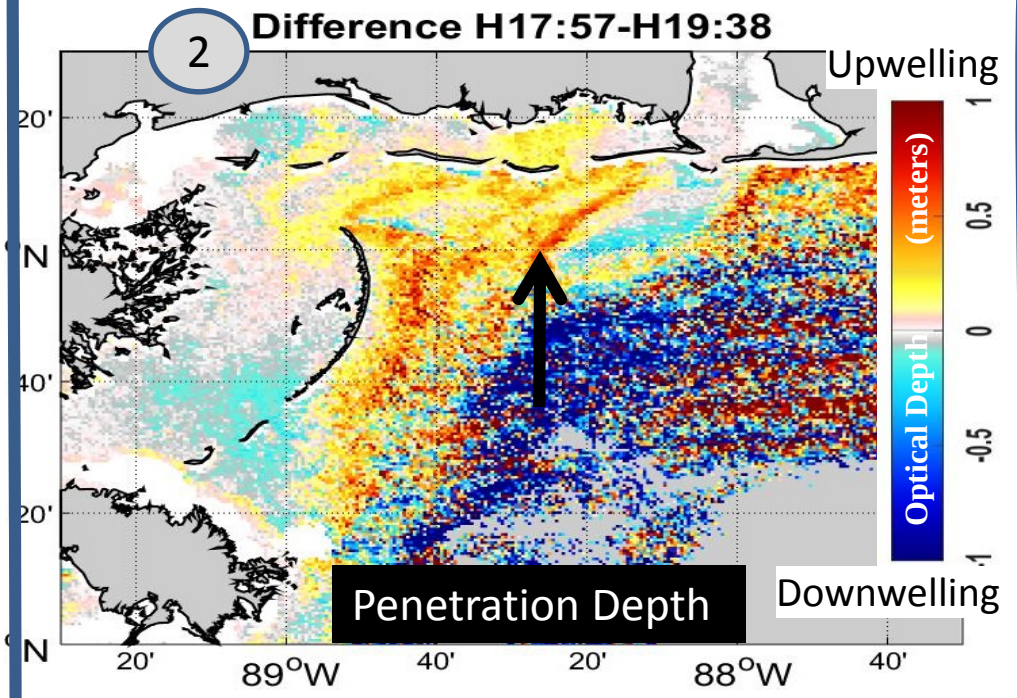


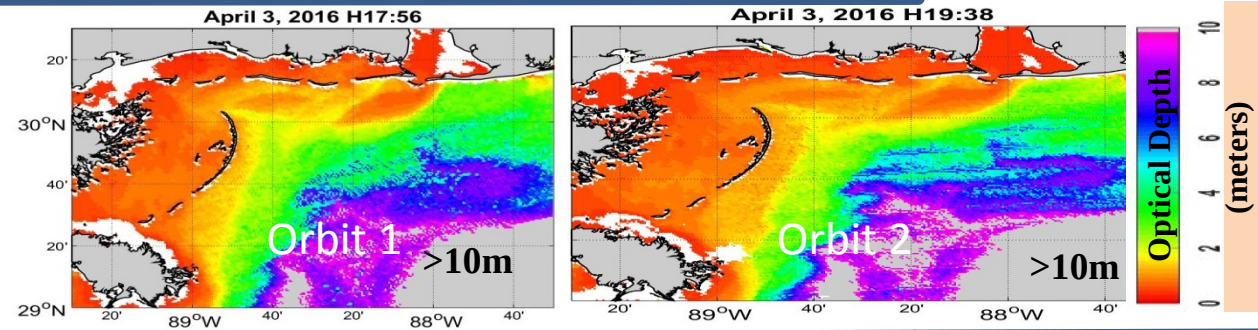
VIIRS Difference Products

1- Backscatter 551 : Particles

2- Satellite Penetration Depth



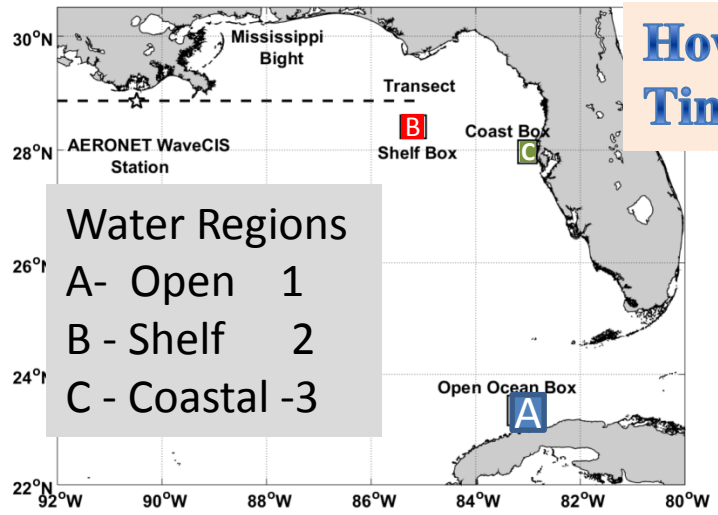




VIIRS Product
Vertical Migration Depth
Within 100 minutes

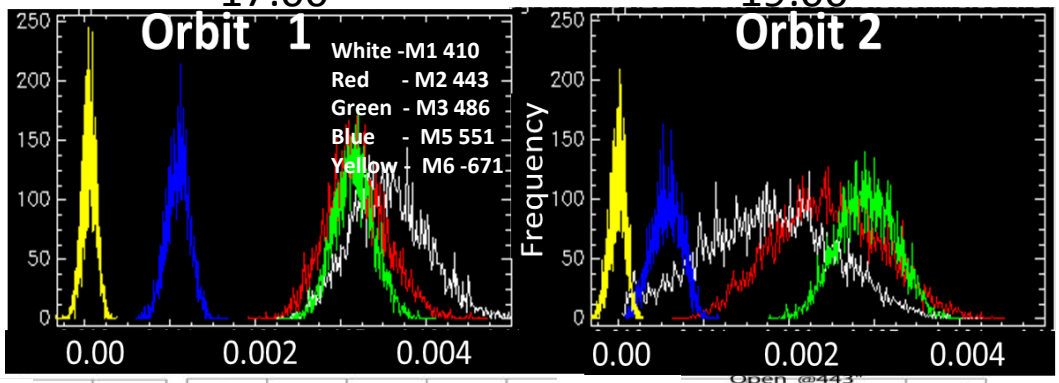
Mobile Plume

How does the Difference Products change Seasonally? Timing of VIIRS Overpass can affect the Ocean Color

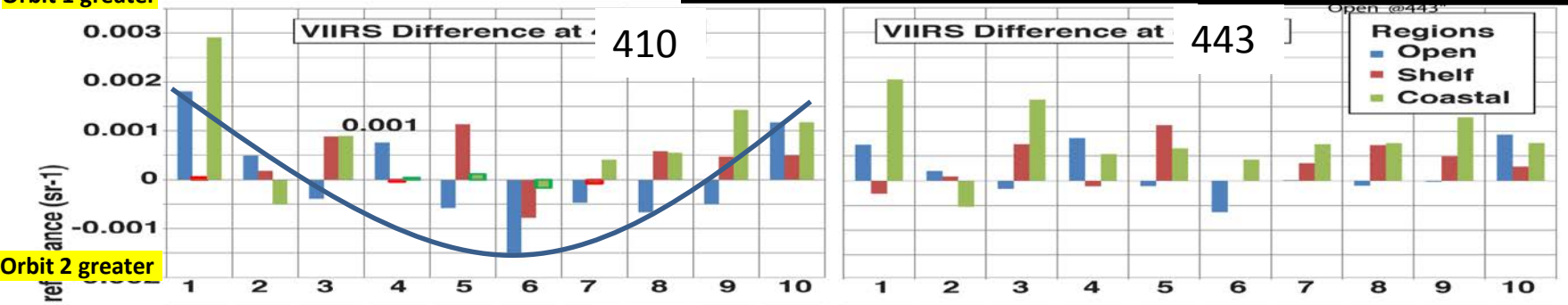


Water Regions
A- Open 1
B - Shelf 2
C - Coastal -3

~17:00 ~19:00

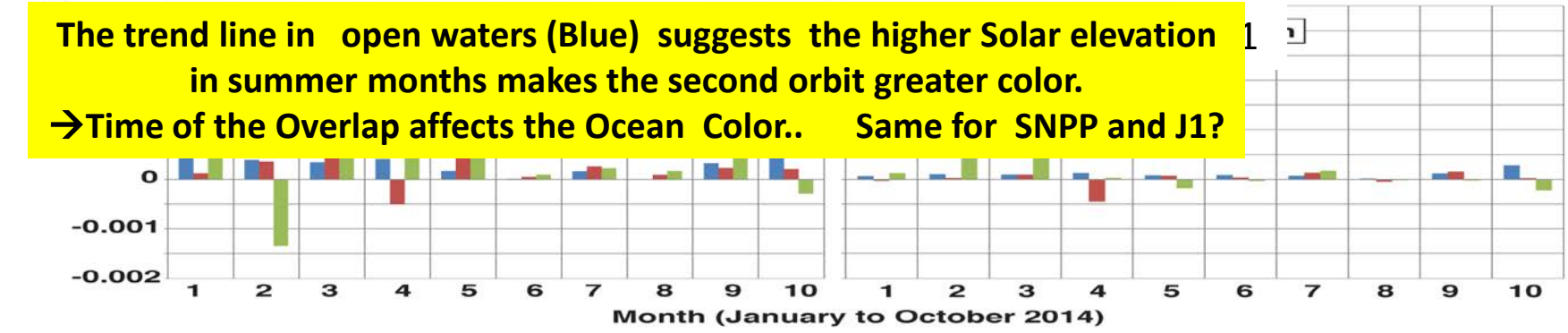


Orbit 1 greater



Orbit 2 greater

The trend line in open waters (Blue) suggests the higher Solar elevation in summer months makes the second orbit greater color.
→Time of the Overlap affects the Ocean Color.. Same for SNPP and J1?



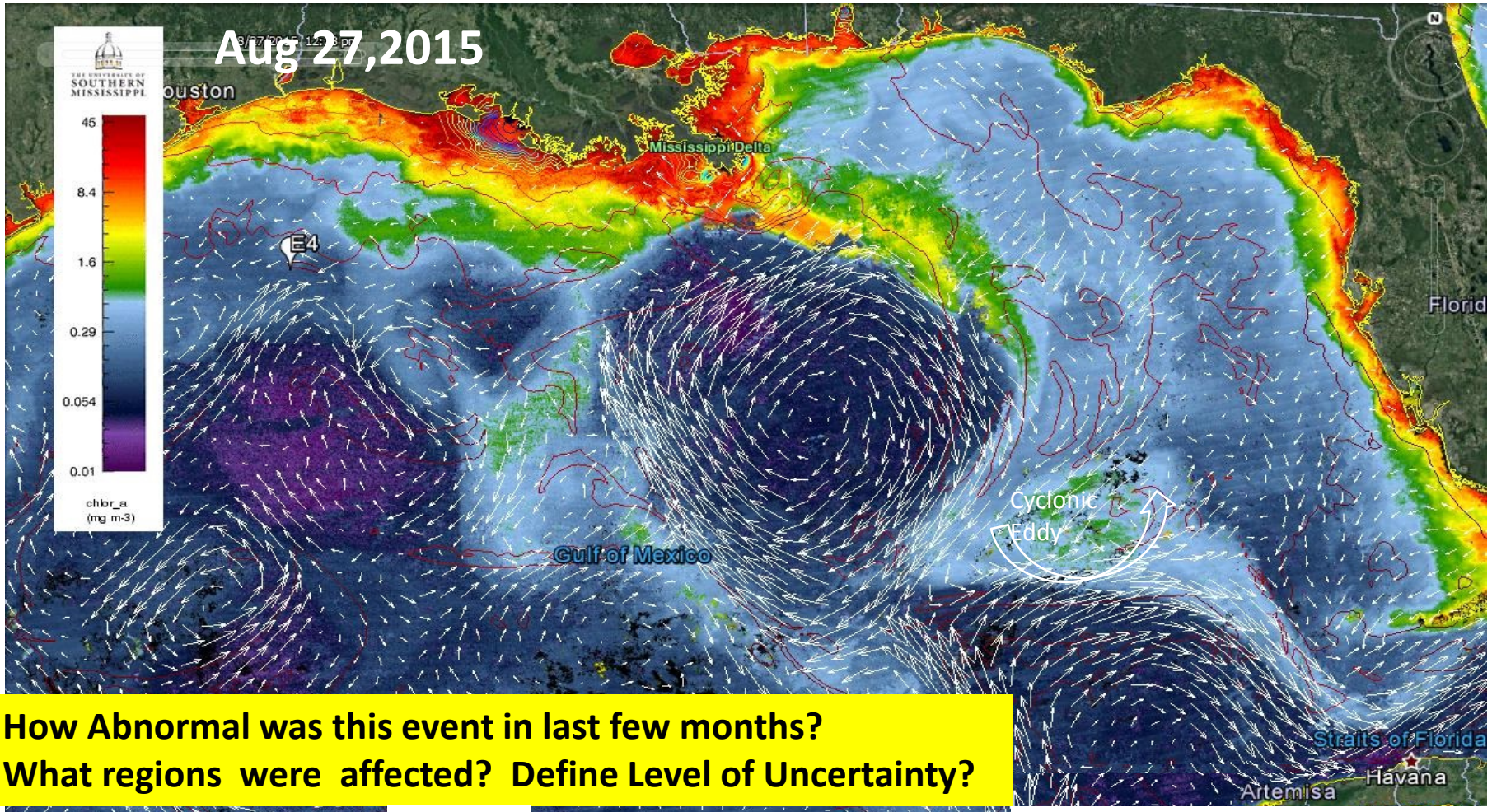
The diurnal difference (orbit 1- orbit2) VIIRS nLW spectral channels (A410, B 443, C551, D671) month 2014

Enhanced VIIRS Products

Identifying Events using VIIRS and Am Seas Model

Events- Mississippi Plume to Key West LOOP Current

Physical and bio-optical Changes to Detect Events and HOTSPOTS



How Abnormal was this event in last few months?
What regions were affected? Define Level of Uncertainty?

Poster

Daily Chlorophyll and Surface Currents and Salinity Contours?

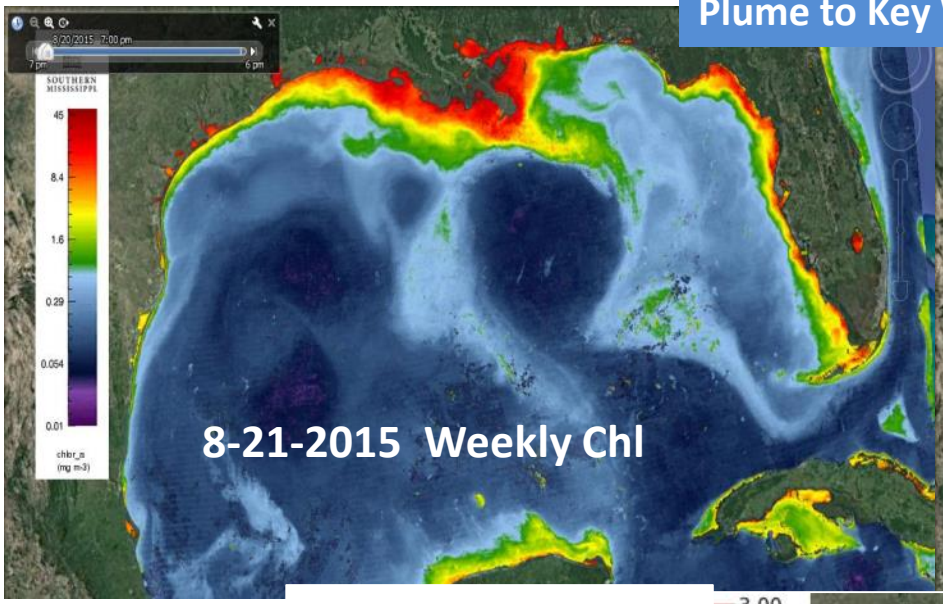
R. Arnone .B. Jones " Monitoring abnormal bio-optical and physical properties in the Gulf of Mexico ", *Proc. SPIE* 10186, Ocean Sensing and Monitoring IX, 101860O (May 22, 2017); doi:10.1117/12.2266789; **http://dx.doi.org/10.1117/12.2266789**

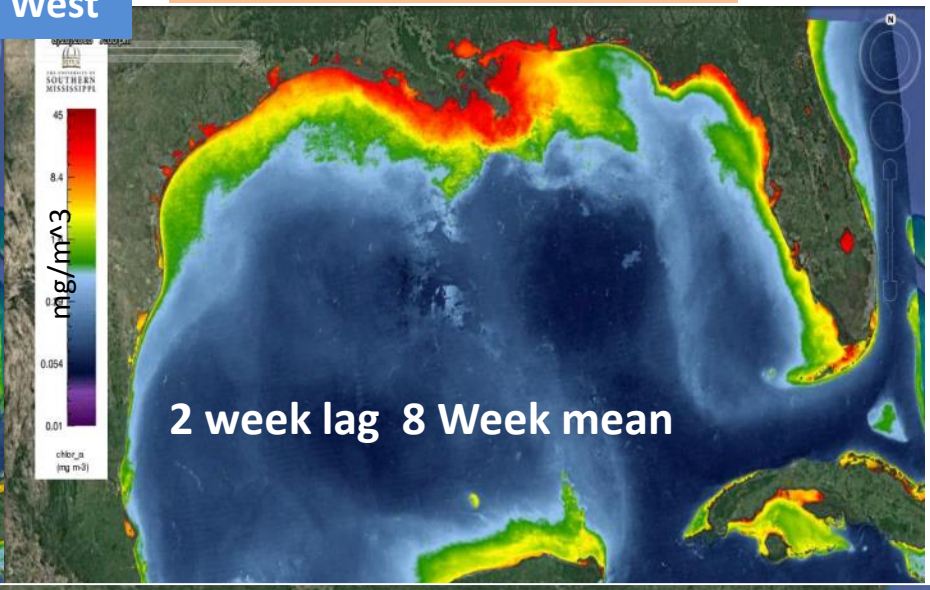
Defining Dynamic Anomalies Properties –DAP

Where are the abnormal Hotspots in 8-21- 2015

Chlorophyll Hotspots

Plume to Key West





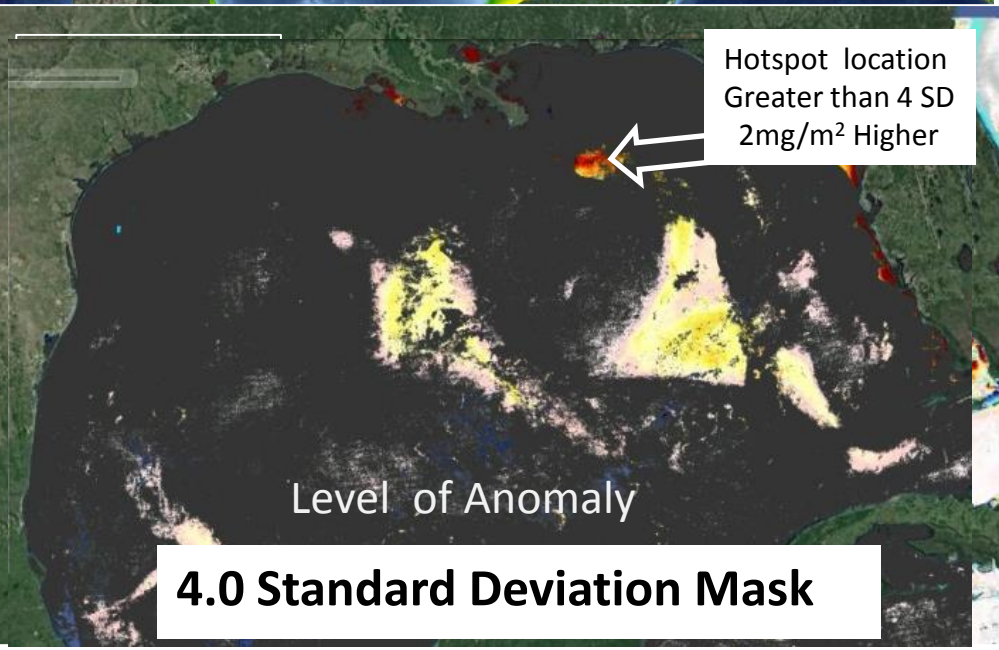
Higher

Normal

Lower

Mg/m²

3.00
1.50
0.00
-1.50
-3.00



Difference

Need to determine the Level of the Anomaly - by a mask of the Standard Deviation

How Abnormal Condition affect the Ecosystem

Coupling Satellite and Ocean Models

VIIRS Products and
America Seas Model

Anomaly Products

Plume to Key West Event Sept 21- 2015

Products

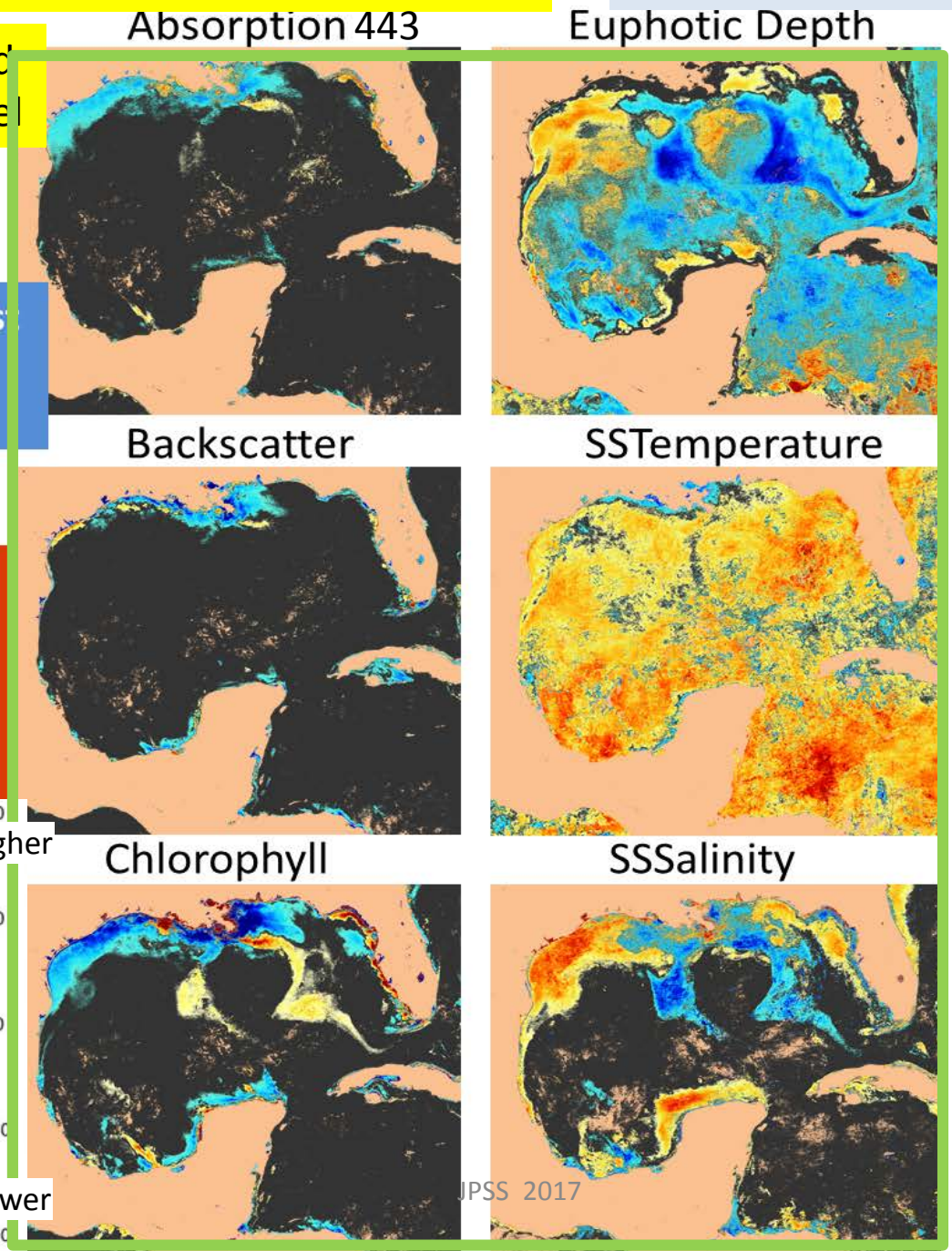
Anomaly

One St-Dev

Weekly
8Week Avg
Anomaly
Stand Deviation

Animation



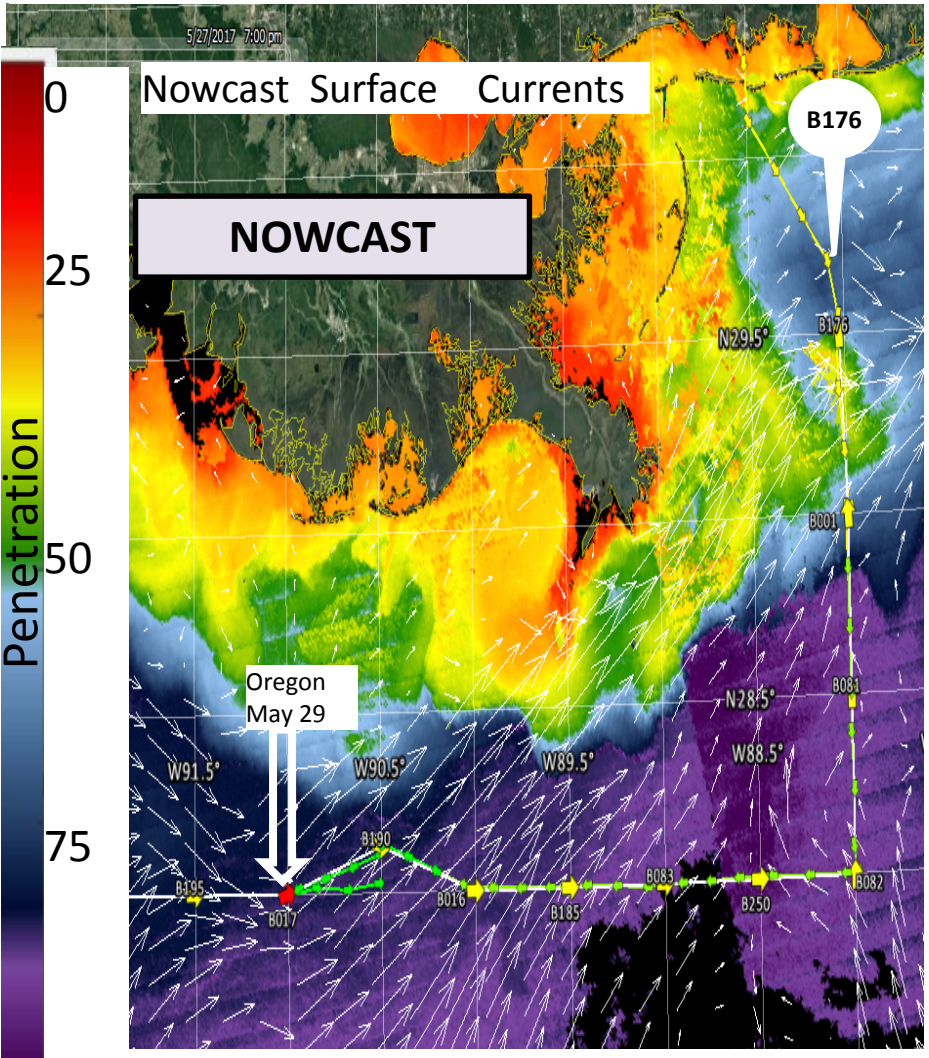


Oregon & Foster Cruise Fishers -- Tuna

Abnormal Patches of more clearer and turbid waters.

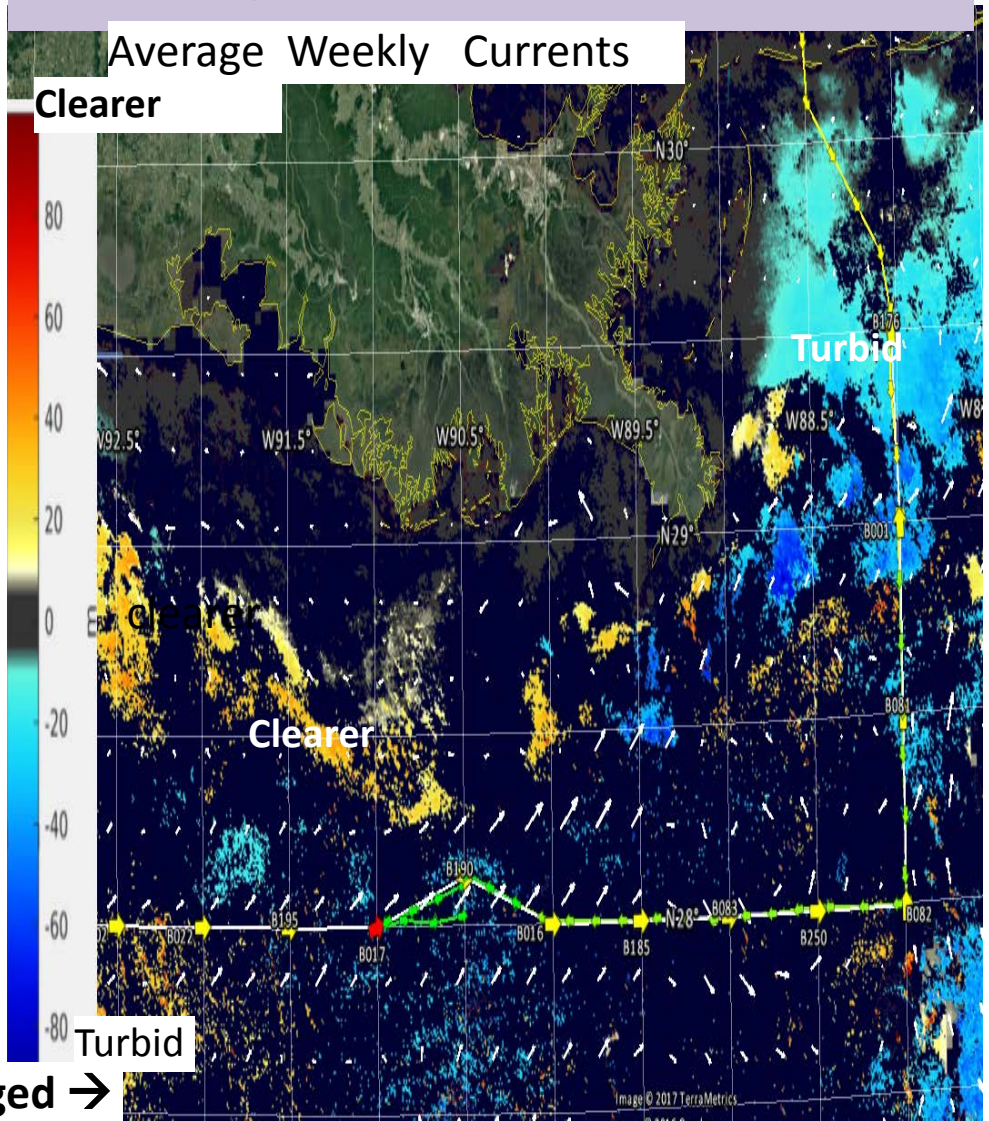
Water Clarity – Euphotic depth

VIIRS Water Clarity May 27



VIIRS Water Clarity Anomaly May 17-24

SD MSK1



Is this typical? What is Different / Changed →

Oregon & Foster Cruise May 2017 Salinity

Nowcast Surface Currents

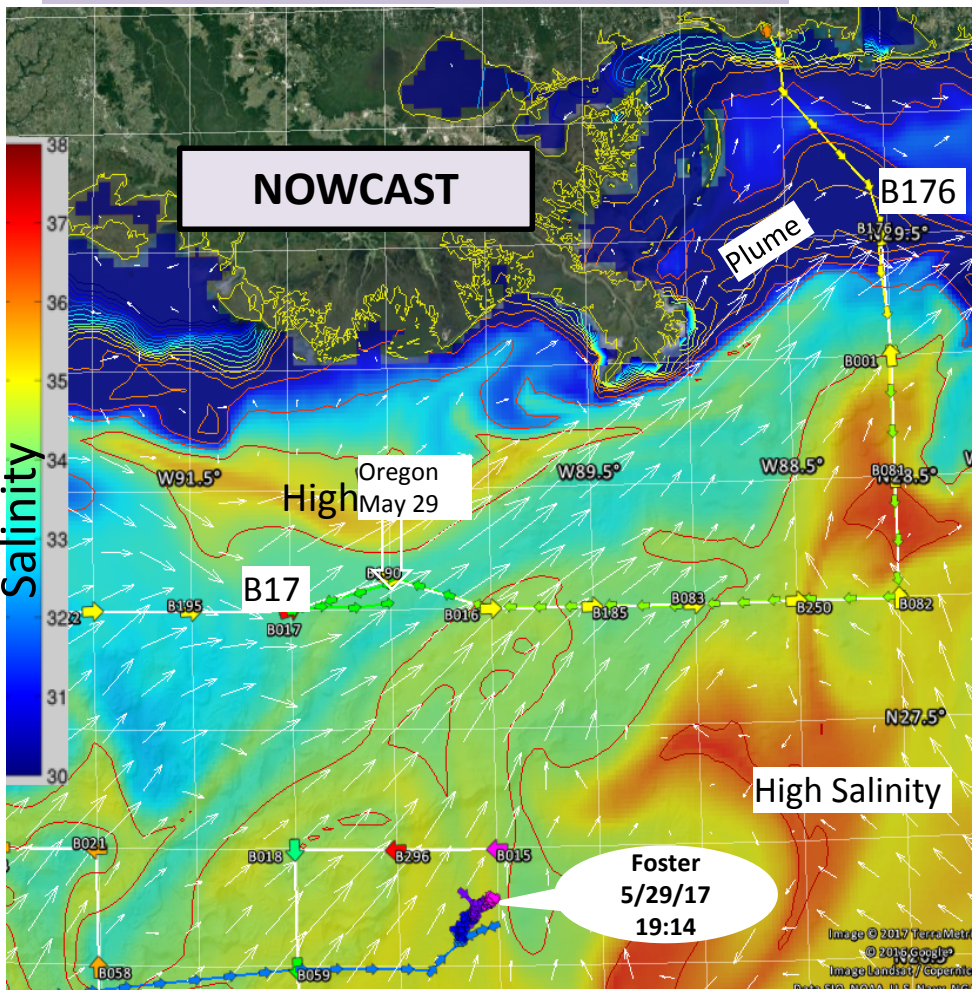
MS plume to EAST

MS- Plume at B176

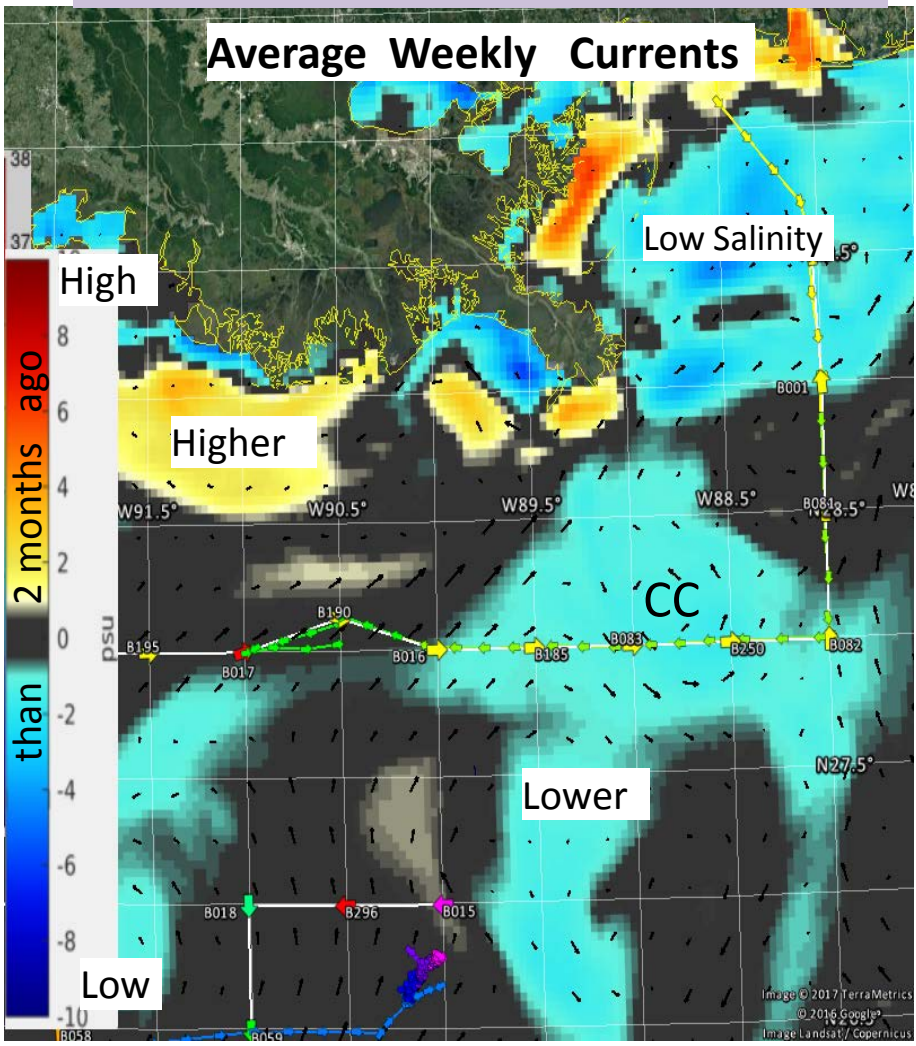
LA- Coast has high Salinity region

Lower Anomaly salinity regions - B176, B185-B082

Surface Salinity May 27



Anomaly May 17-24 SD MSK1

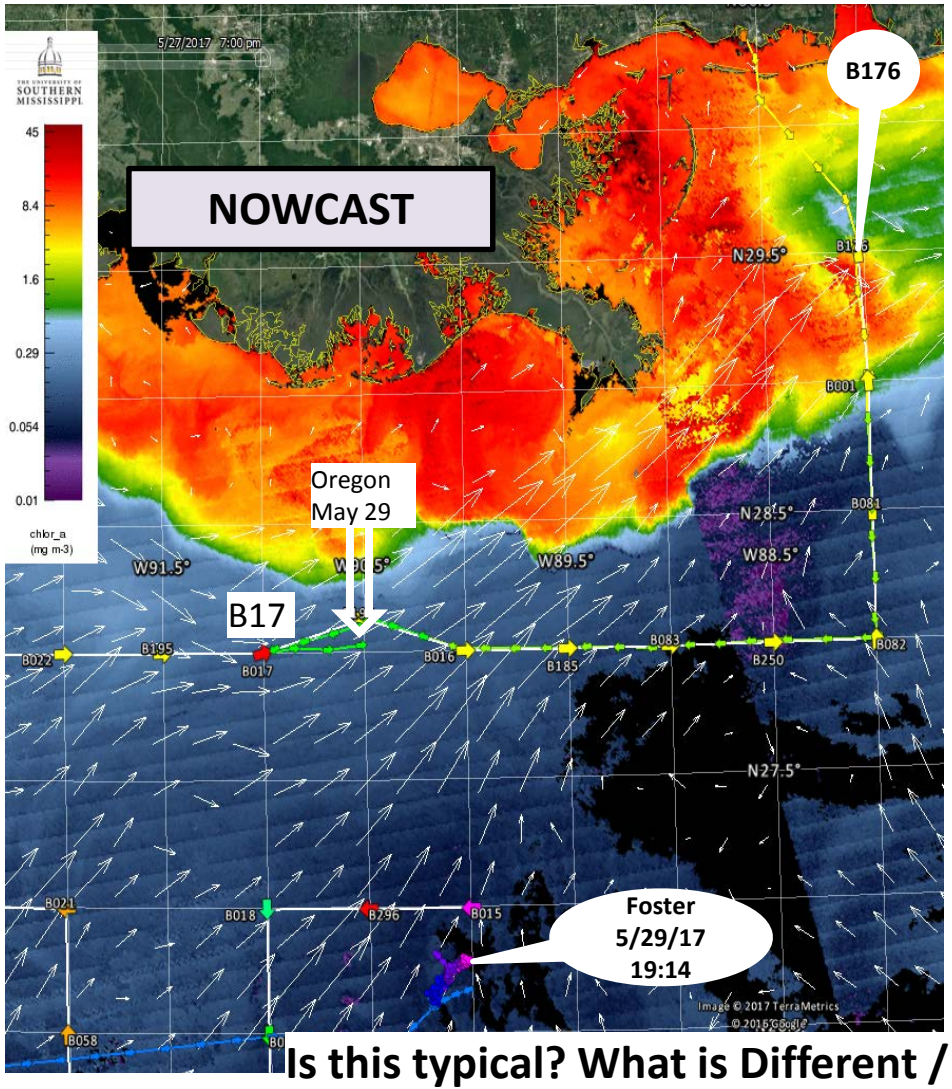


Is this typical? What is Different / Changed

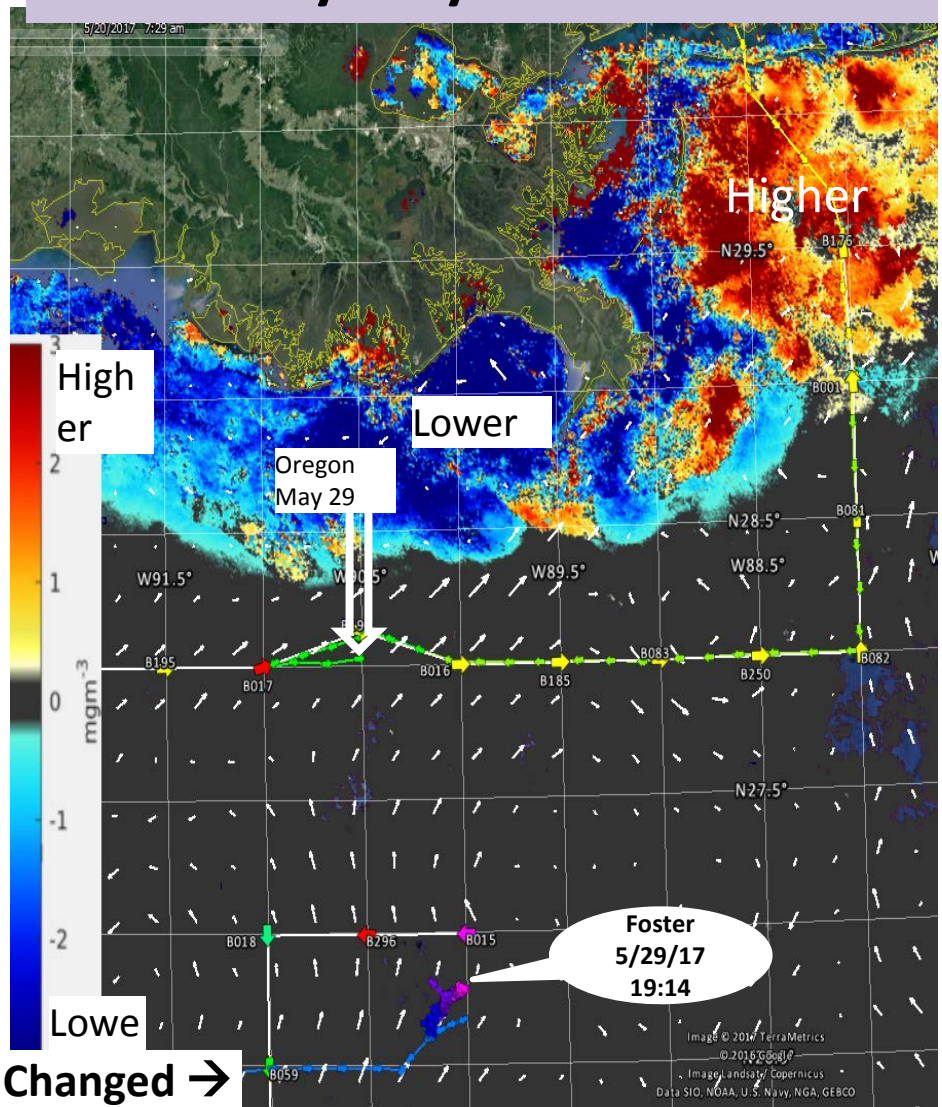
Oregon Foster Cruise
May, 2017 Chlorophyll

Chl- Extending Offshore ! Anomaly Chlorophyll -
Lower along LA coast -
Higher along MS coast

Chlorophyll May 27



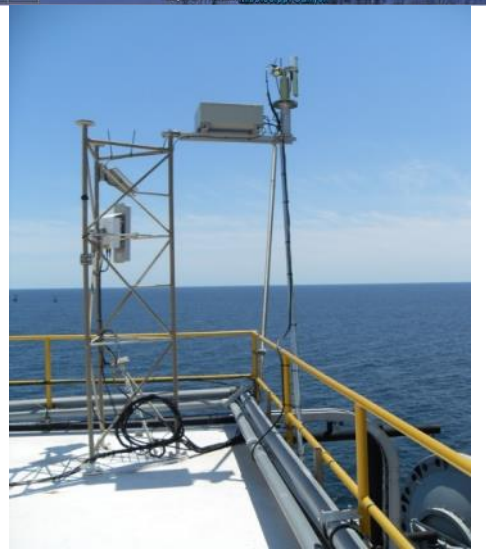
Anomaly May 24- 17 SD MSK1



Is this typical? What is Different / Changed →

Annual Status of WavCis CSI SeaPrism Status Operational -- June 2016- – Aug 2017 SN 610 and SN 638





Instrument Update and Present Status:

A . New Owners of ST52B purchased this platform in November of 2016, new boarding agreement in place by end of March, 2017.

B. SN610 - Operational to Sept 2016 and replaced with SN638 Loaner.

C. SN638 – Operational to May 8, 2017, and replaced with SN610. Returned to NASA recalibrated SN638.

ALL data upgraded to Level 2.

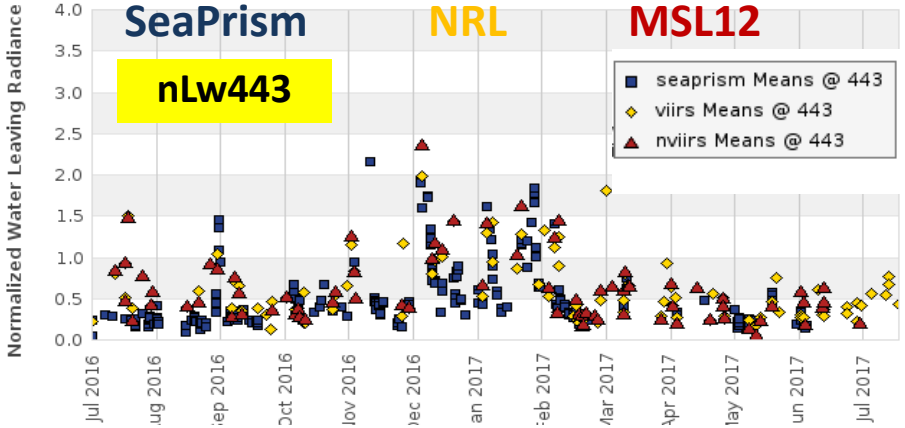
D. ***Problems/ Issues this year 2017.***

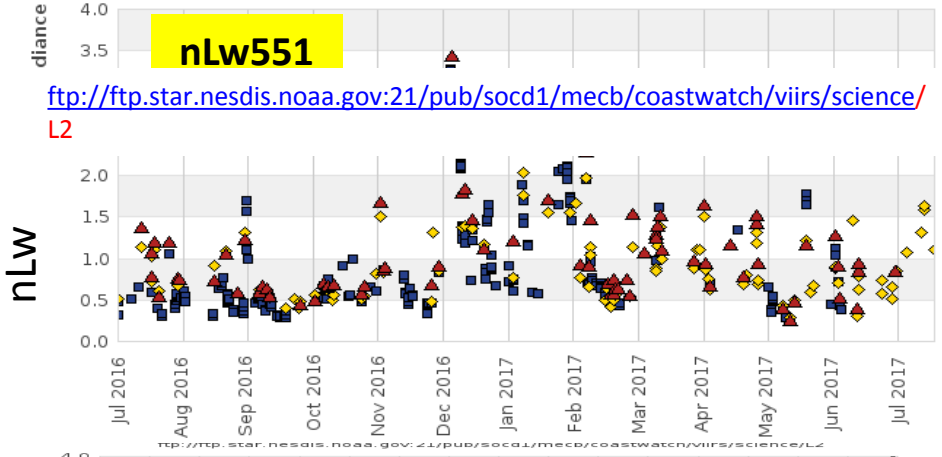
1. April 10th, platform generators down, replaced both battery chargers, main batteries and computer power supply. Site repaired and running.
2. April 30th Platform Lightning strike . Replaced Serial communications on SN 638, PC Serial Data cable and USB RS 232 Port hub. Computer cooling and other subsystems repaired. Back up and verified via the Aeronet Web site.
3. May 26th- SeaPrism time data was not being updated. Corrected problem by installing latest HTTP CIMEL program.
4. SN 638 returned from Goddard in early July, 2017.
5. Presently, main battery might be dead (last replaced in 2013), delays due to bad weather. Sn 638 will be reinstalled ASAP and SN 610 will be returned to NASA. Check Filter Wheel motor.

WaveCIS –CSI "nLw" Operational FULL Time Series

July 2017 – July 2017

lwn_f/Q





CSI Site Matchups this Year

262 points for WaveCIS (4-6 readings/day)

102 for Navy APS VIIRS,

77 for MSL12 VIIRS

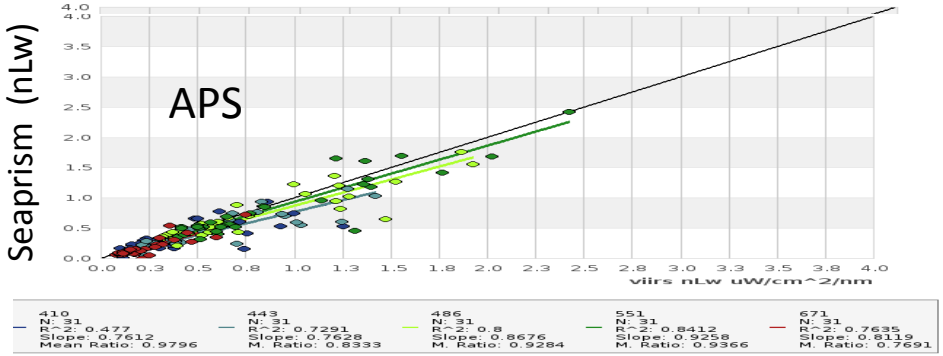
Constraints: Valid

50% of 5x5 box centered around in-situ sensor

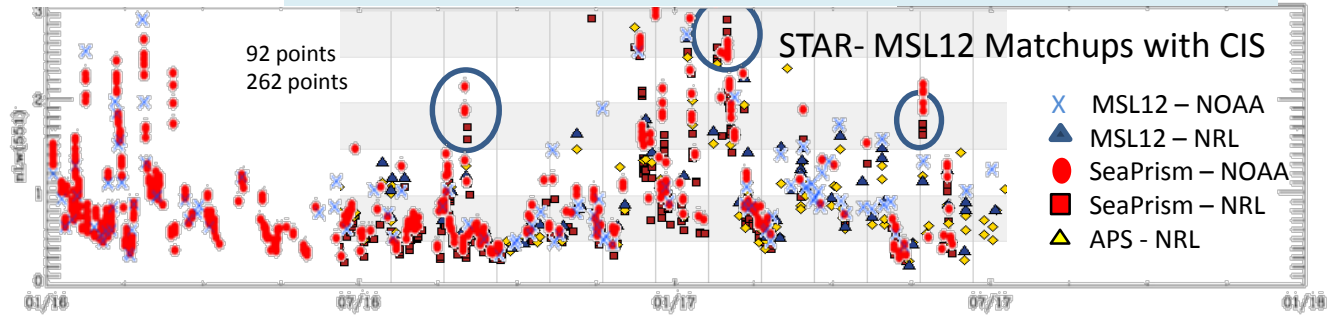
Center pixel valid (WavCis Site Location)

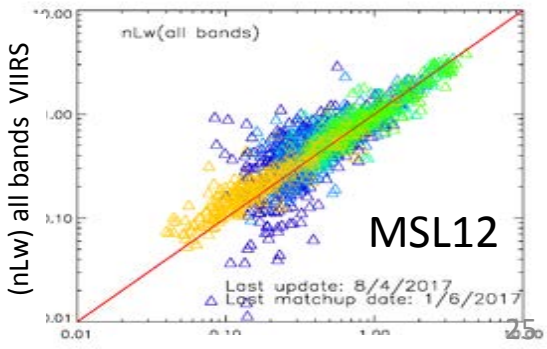
nLw between 0-4

Flagged for CLDICE, HIGLINT, ATMFAIL, PRODFAIL



Note Differences in WavCIS matchup *(MSL12, NRL)*





(nLw) all bands WavCis

Summary

1. Oct 2016 Foster cruise
   Match up with Hyperpros , ASD and Flowthrough
   Coastal waters – *Trichodesmium*
   Protocols for Floating Hyperpro, and IOP-acs

2. Diurnal ocean color using VIIRS Orbital Overlaps - → J1 /NPP Compare
   New VIIRS Difference products. Vertical optical layers , Bloom etc
   VIIRS overlaps support for a Geostationary Sensor !

3. Dynamic Abnormal properties - "Hotspots" using VIIRS and Physical models

4. WavCis – Aeronet Operational and Calibrated at NASA

Thank You

Stennis - Cal val Team
Annual Summary

Invitation: Call for Papers

SPIE – Security and Defense

OCEAN SENSING AND MONITORING X

http://www.spie.org/oceans/
April 15-19, 2018
Gaylord Palms Convention Center
Orlando, Florida, USA

Conference Chairs: **Weilin "Will" Hou**, Naval Research Lab), **Robert A. Arnone**, Univ. Southern Mississippi
Program Committee: **Sam Ahmed**, City College of New York **Linda Mullen**, Naval Air Systems Command **Brandon Cochenour**, Naval Air Systems Command; **Fraser Dalgleish**, Florida Atlantic University); **Chuanmin Hu**, University of South Florida) ; **James Sullivan**, Florida Atlantic University ; **Michael Twardowski**, Florida Atlantic University

Sessions:

A. Ocean Remote Sensing: Lidar, Ocean Color, SST, SAR

active and passive remote sensing of the ocean and atmosphere (visible, IR/SST, microwave/SAR)
inversion techniques for active and passive measurements
calibration and characterization of satellite sensors
cloud screening and effect of ambient/residual cloud on retrievals
Cal/Val, quality control and consistency checks of satellite products, inter-sensor comparisons
uncertainty evaluation
radiative transfer in the ocean and atmosphere

B. In Situ Sensing and Monitoring

C. Extreme Events: Oil Spill & Harmful Algal Bloom (HAB) Sensing and Monitoring

D. Unmanned Systems, Sensors, Measurements

E. Imaging Sensors, Systems and Signal Processing Techniques: Optical & Acoustical

F. Characterization and Forecasting of Oceanic, and Coastal Environments

G. Bioluminescence

Thank You

END

Evaluation of VIIRS performance in coastal waters and in its capacity to detect dark water and harmful algal blooms

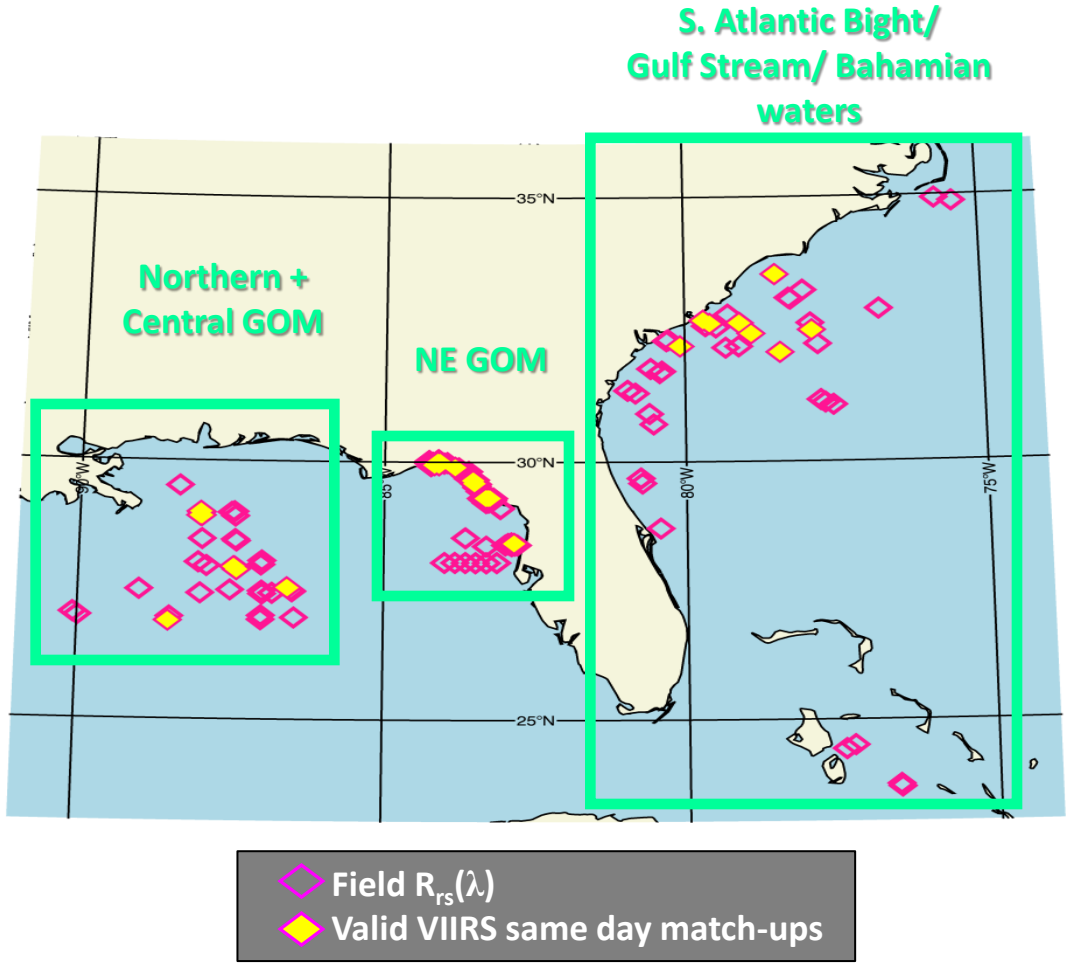
Chuanmin Hu, David English, Jennifer Cannizzaro, Brian Barnes, Lin Qi
Optical Oceanography Laboratory,
College of Marine Science,
University of South Florida

1. Performance for open-ocean and coastal waters
2. Performance for estuaries
3. Application for harmful algal blooms
4. Application for floating macroalgae blooms

1. Performance for open-ocean and coastal waters

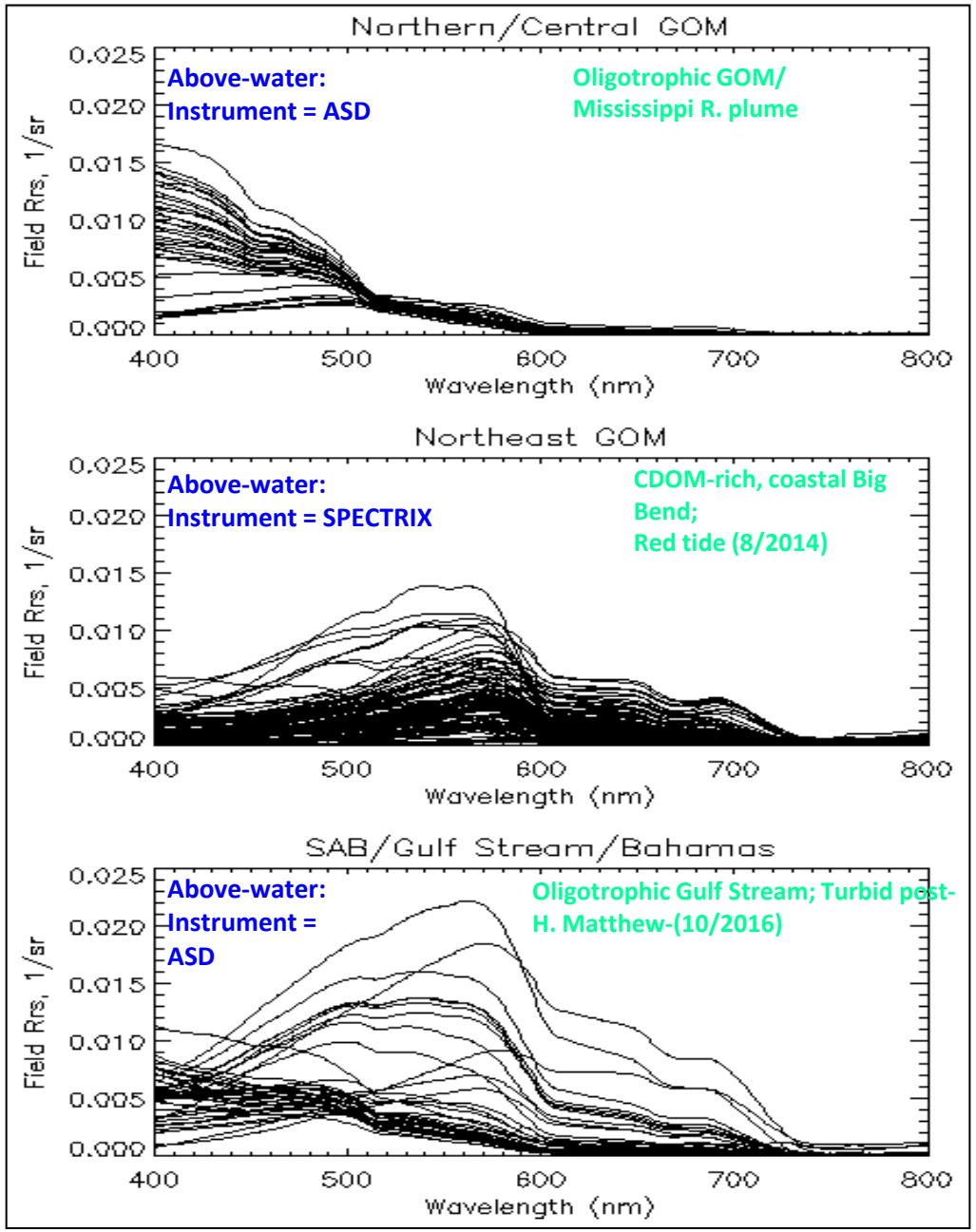
Summary of USF Field Experiments in oceanic/coastal waters (2012-2016)

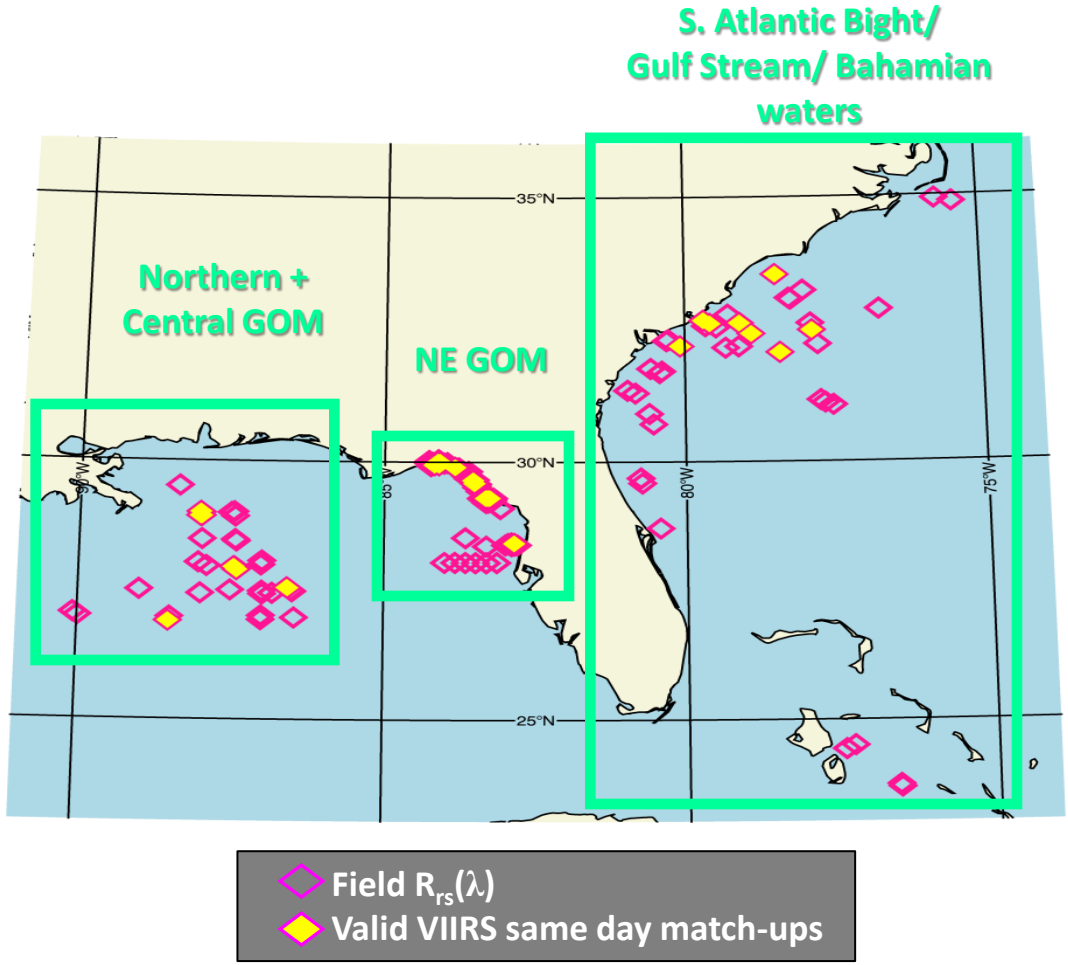
Region	Project	Cruise	Start Date	End Date	Field $R_{rs}(\lambda)$	
Northern and Central Gulf of Mexico	GoMRI DEEPEND	DP01	05/01/15	05/08/15	7	n=35
		DP02	08/08/15	08/22/15	13	
		DP03	05/01/16	05/16/16	8	
		DP04	08/05/16	08/20/16	7	
Northeastern Gulf of Mexico	HAB event response	BE1408	08/04/14	08/05/14	8	n=104
	NASA Big Bend	SC1209	09/28/12	09/28/12	8	
		CK1211	11/15/12	11/15/12	5	
		HICO	10/26/13	10/26/13	9	
			11/17/13	11/17/13	14	
			11/21/13	11/21/13	13	
			04/11/14	04/11/14	10	
		bb1606	06/08/16	06/08/16	4	
			06/10/16	06/10/16	2	
			06/13/16	06/13/16	2	
			06/14/16	06/14/16	3	
			06/20/16	06/20/16	4	
			06/21/16	06/21/16	3	
			06/22/16	06/22/16	1	
			06/23/16	06/23/16	3	
		bb1607	07/20/16	07/20/16	5	
		bb1610	10/03/16	10/03/16	10	
South Atlantic Bight, Gulf Stream, and Bahamian waters	NOAA VIIRS Cal/Val	NF-14-09	11/11/14	11/20/14	7	n=45
		NF-15-13	12/02/15	12/13/15	26	
		NF-16-08	10/13/16	10/18/16	12	



Total # of field $R_{rs}(\lambda)$ = 184

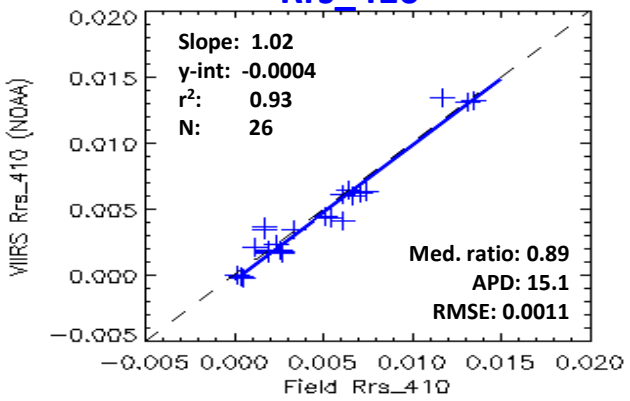
Summary of USF Field Experiments in oceanic/coastal waters (2012-2016)



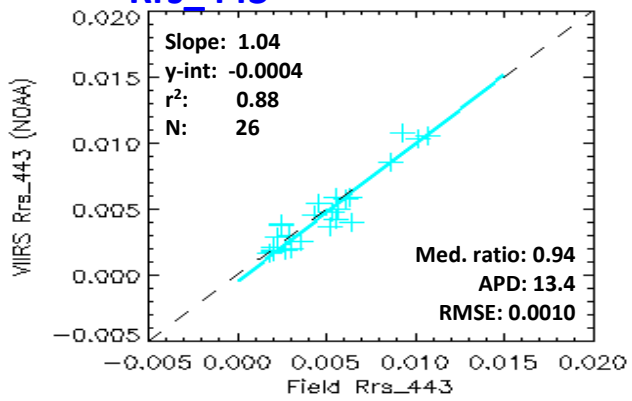


‘Old’ VIIRS MSL12

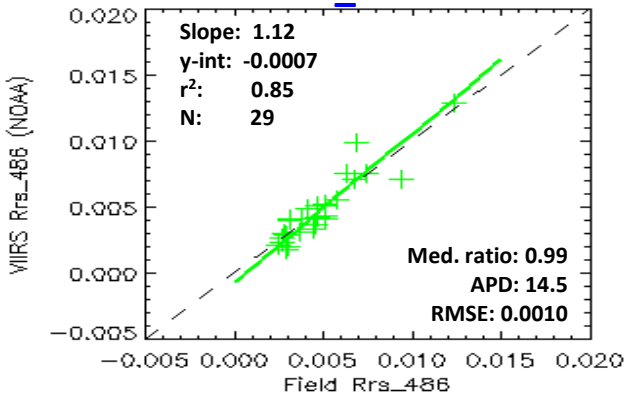
Rrs_410



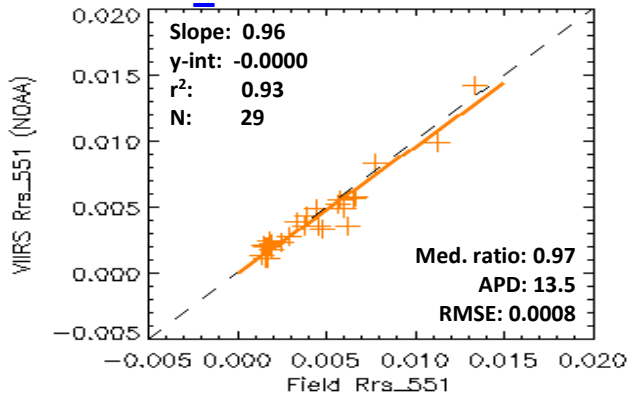
Rrs_443



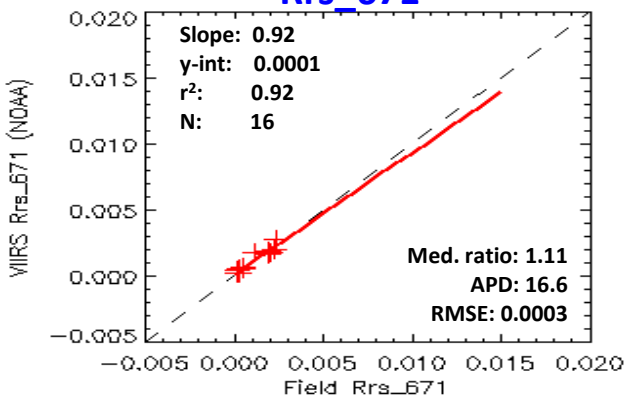
Rrs_486



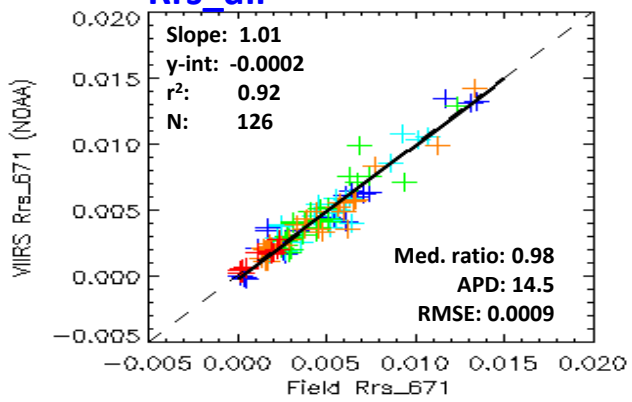
Rrs_551



Rrs_671

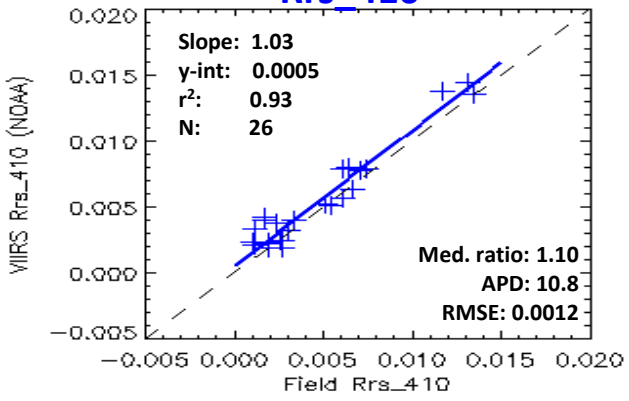


Rrs_all

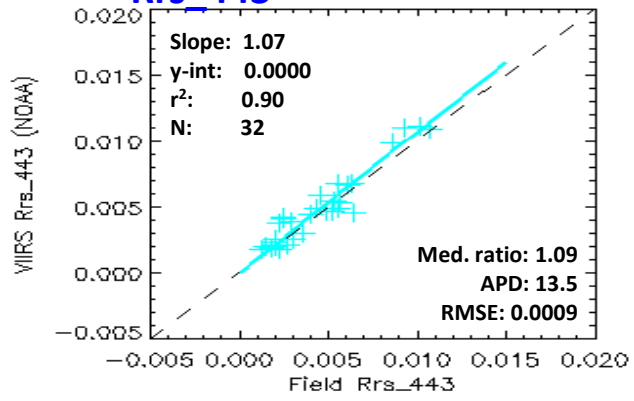


‘New’ VIIRS MSL12

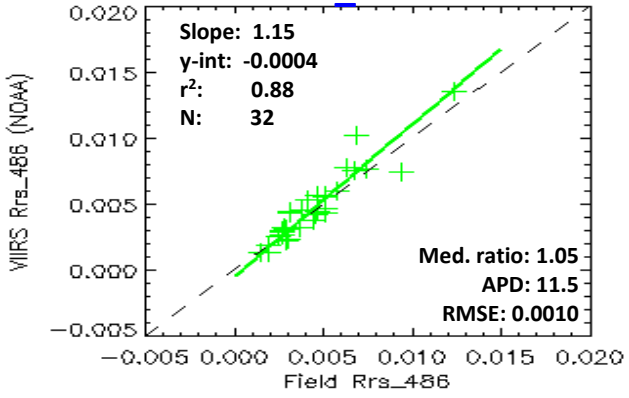
Rrs_410



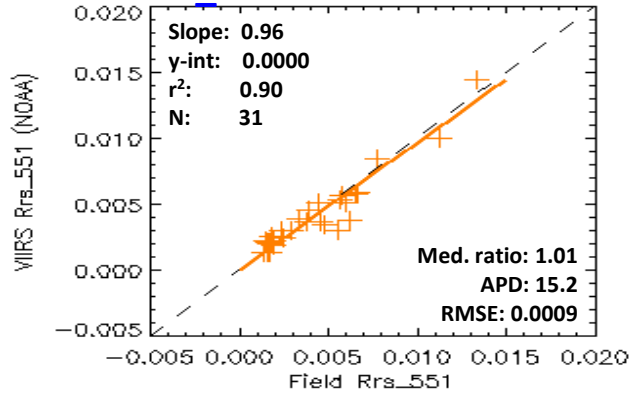
Rrs_443



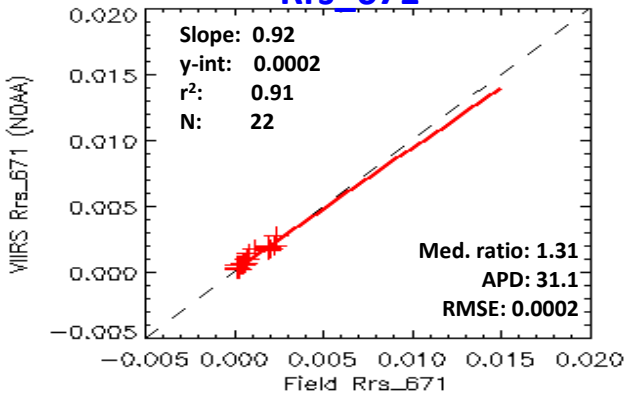
Rrs_486



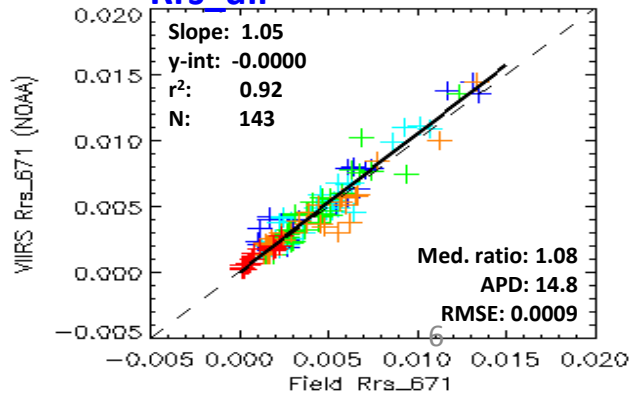
Rrs_551



Rrs_671



Rrs_all



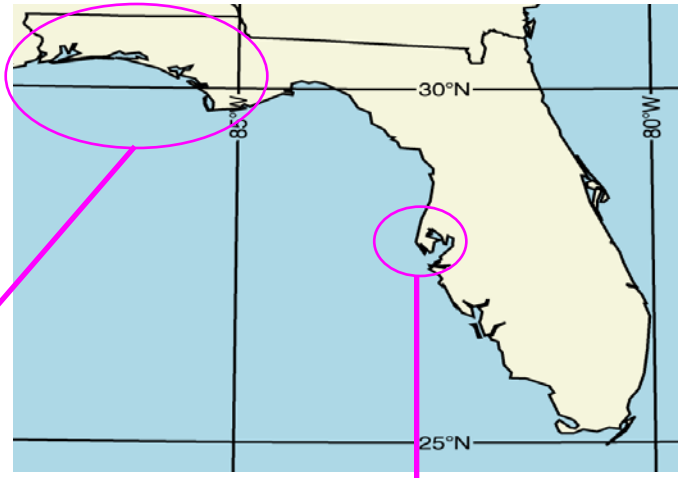
2. Performance for estuaries

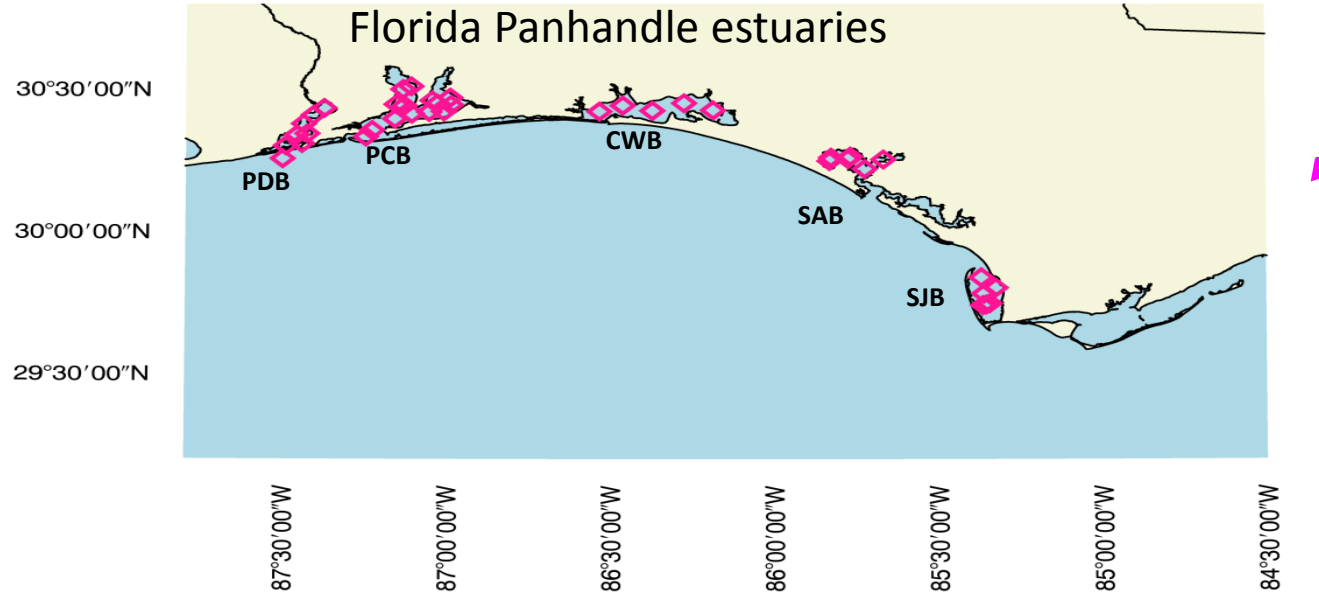
Summary of USF Field Experiments in estuarine waters (2012-2016)

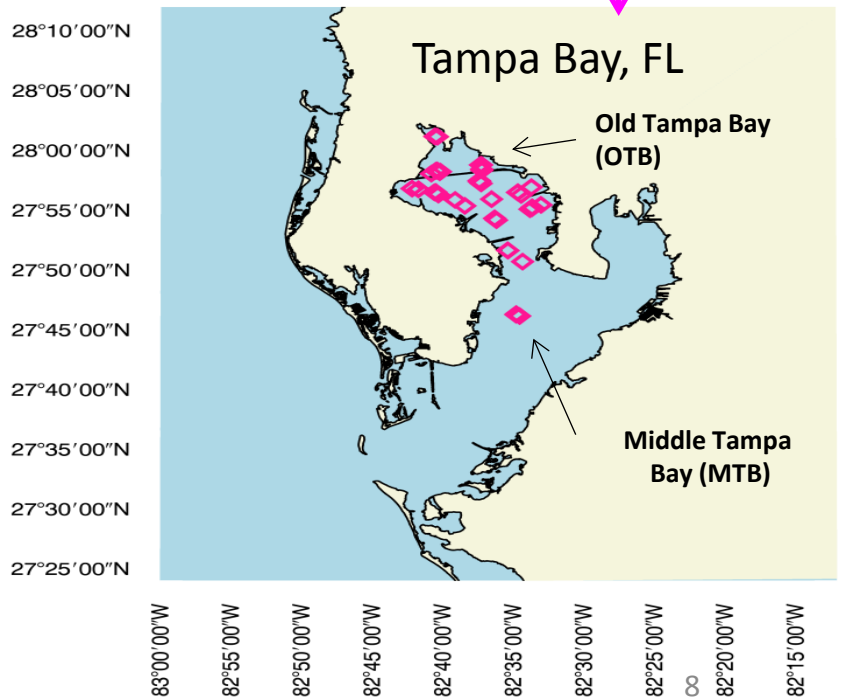
Start Date	End Date	Project	Cruise_ID	Region	[Chl *a*]	$a_p(\lambda)$, $a_d(\lambda)$	$a_{CDOM}(\lambda)$	$b_b(\lambda)$	$R_{rs}(\lambda)$
01/20/12	12/18/13	HAB Event Response	-	Old Tampa Bay/ Middle Tampa Bay	347	348	348	200	44
05/07/12	-	NASA-Tampa Bay	t1205		7	7	7	0	7
08/24/12	-	NASA-Tampa Bay	t1208		6	6	6	0	6
12/15/15	-	Florida FWC Panhandle estuaries NOAA VIIRS Cal/Val	pan1512	PCB	9	0	9	0	10
12/16/15	-		pan1512	CWB	5	0	5	0	0
12/01/15	-		pan1512	SAB	4	0	4	0	4
03/14/16	-		pan1603	PDB	1	0	1	0	1
03/16/16	-		pan1603	CWB	4	0	4	0	4
05/18/16	-		pan1605	SJB	3	0	3	0	3
05/19/16	-		pan1605	SAB	2	0	2	0	2
05/21/16	-		pan1605	CWB	5	0	5	0	5
05/22/16	-		pan1605	PCB	11	0	11	0	11
05/23/16	-		pan1605	PDB	7	0	7	0	7
07/22/16	-		pan1607	SJB/SAB	8	0	7	0	8
07/24/16	-		pan1607	PCB	3	0	3	0	3
07/25/16	-		pan1607	PCB	1	0	1	0	1
				TOTAL:	423	361	423	200	116

n=57

n=59

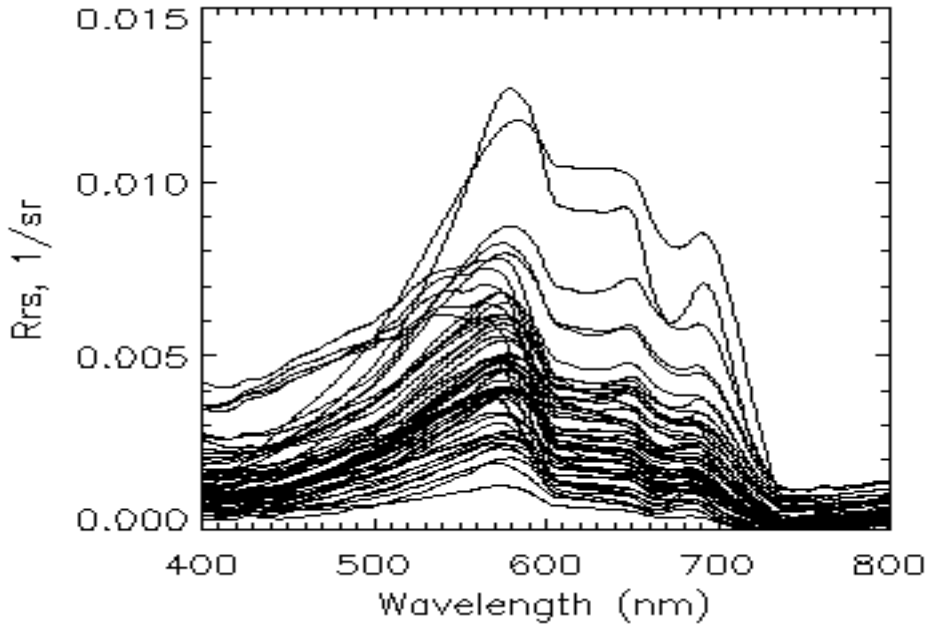






Field $R_{rs}(\lambda)$:

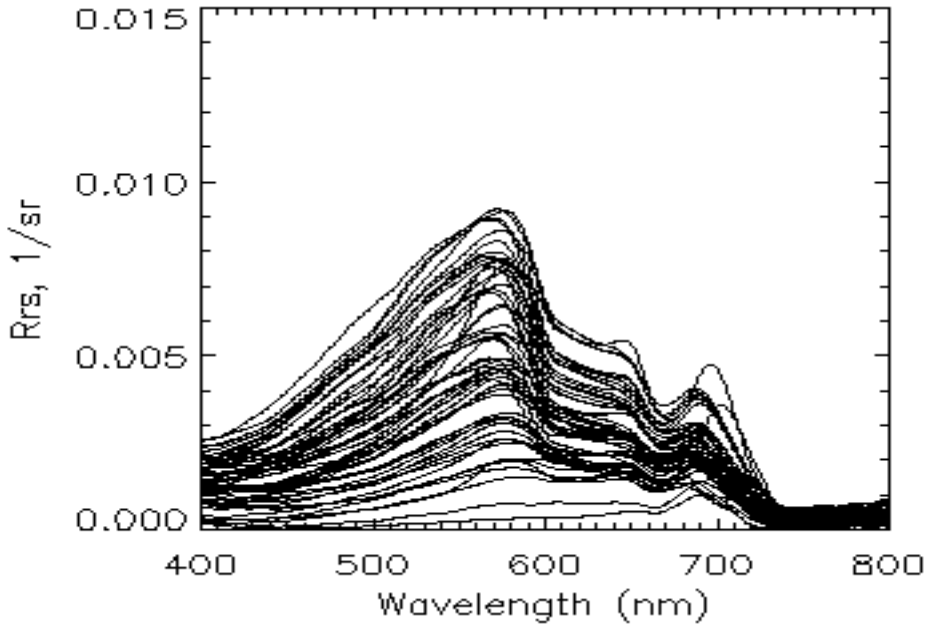
Florida Panhandle estuaries (n=59)



Chl-a: 0.91 – 11.9 mg m $^{-3}$
4.9 ± 2.8 mg m $^{-3}$

$a_{CDOM}(443)$: 0.05-1.7 m^{-1}
0.91 ± 0.40 m^{-1}

Tampa Bay, FL (n=57)



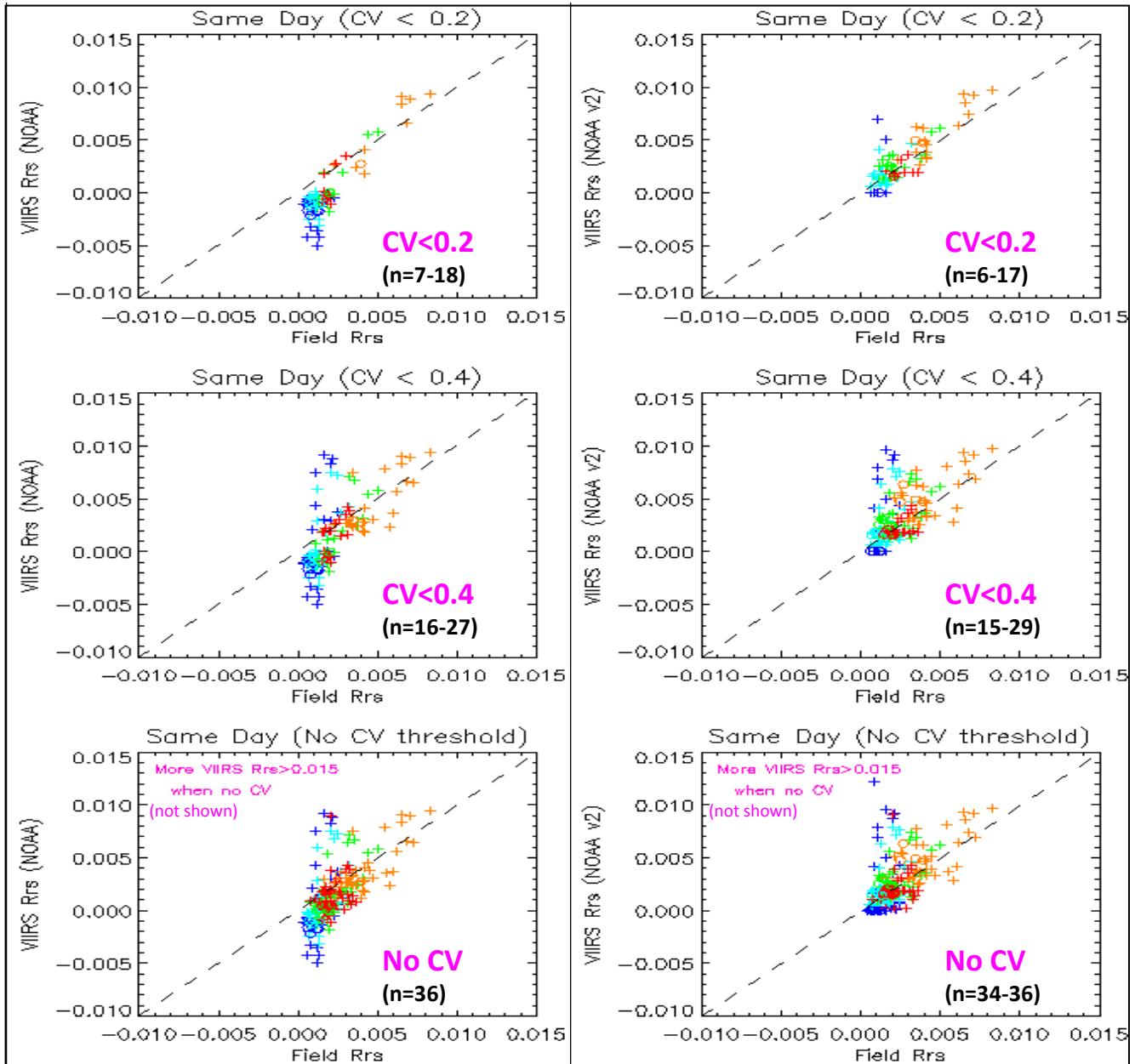
Chl-a: 3.0 – 53.6 mg m $^{-3}$
12.6 ± 10.2 mg m $^{-3}$

$a_{CDOM}(443)$: 0.36 – 11.0 m^{-1}
1.4 ± 1.7 m^{-1}

VIIRS $R_{rs}(\lambda)$ match-up results: *variable processing schemes/spatial homogeneity filters; standard l2 flags applied*

NOAA (v1 – aka "old") NOAA (v2 – "new") ←*processing*

(most recent processing)



410nm
443nm
486nm
551nm
671nm

Observations:

- Important: *cannot directly compare processing schemes using data shown here!* Why? Because the dates and locations of match-up pairs differed greatly amongst processing schemes. For example: only 4 match-up pairs were available when field and VIIRS Rrs(551) using all three processing schemes were valid.
- Relaxation of spatial homogeneity filter led to increased # of match-up pairs, but poorer match-up quality.
- Agreement between field and VIIRS Rrs(λ) weakest at 410nm.

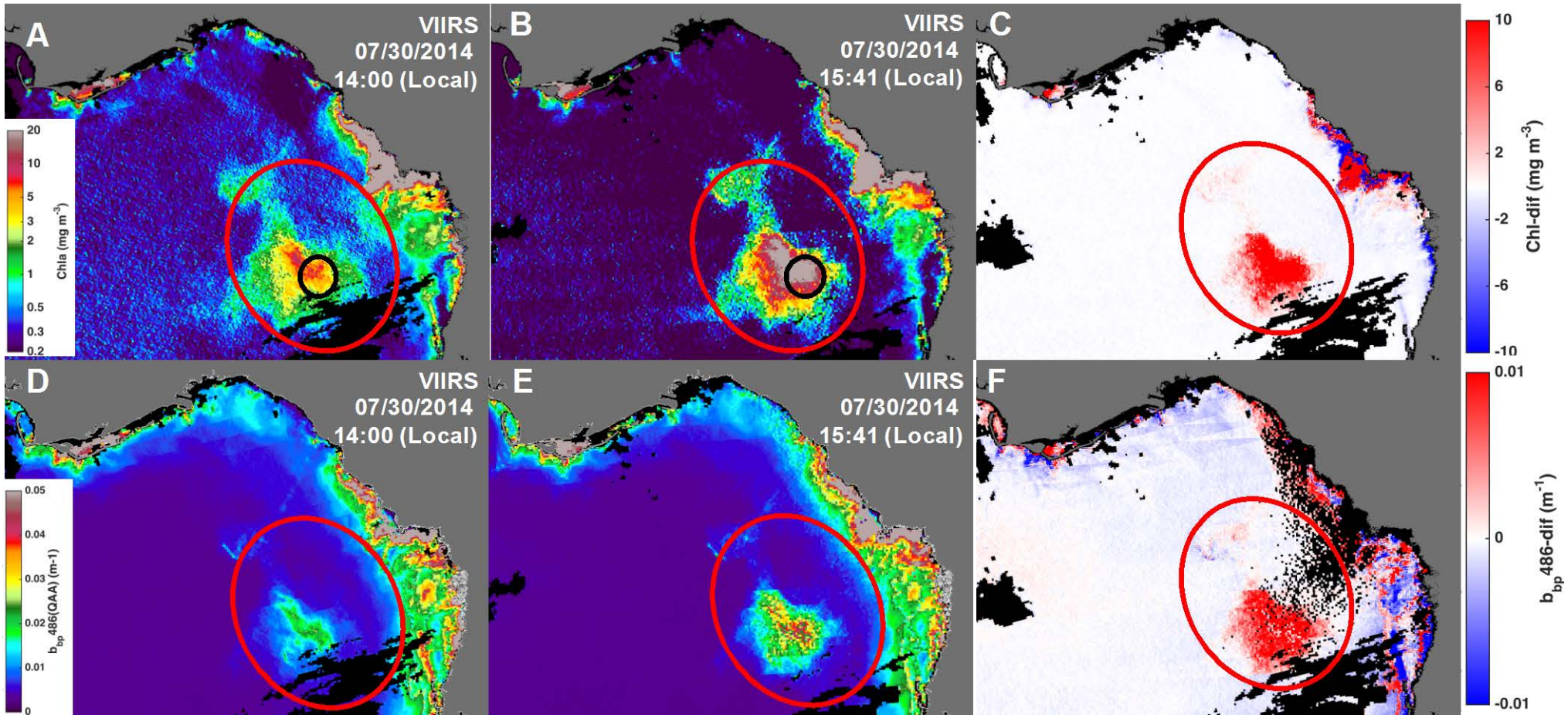
3. Application for harmful algal blooms

VIIRS captures phytoplankton vertical migration in the NE Gulf of Mexico

14:00 hour | 15:41 hour | Difference

Chl =>

b_{bp} =>



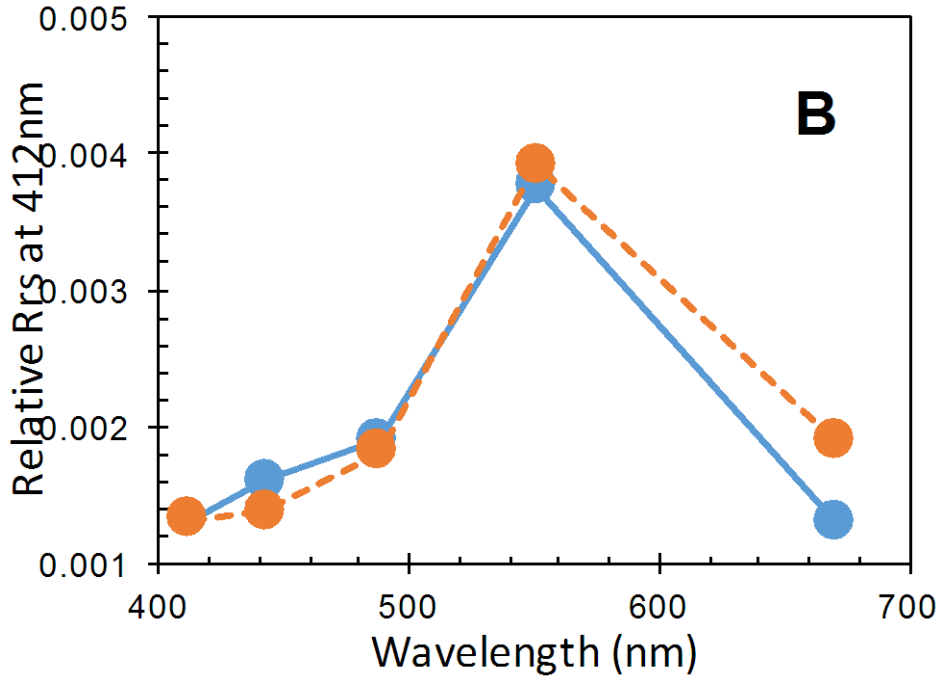
Karenia brevis bloom (red tide), from Qi et al. (2017, Harmful Algae)

VIIRS captures phytoplankton vertical migration in the NE Gulf of Mexico

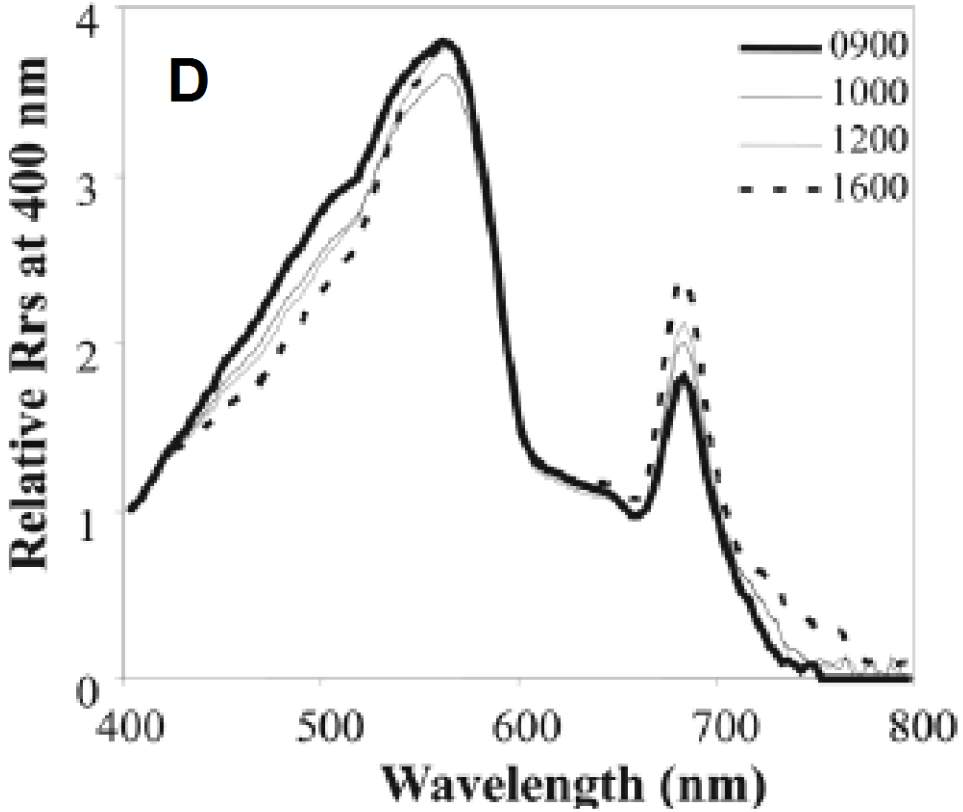
Rrs spectral changes in 100 minutes (left) agree with previous field measurement (right)

From VIIRS measurements, July 30, 2014

Blue: 14:00; Brown: 15:41



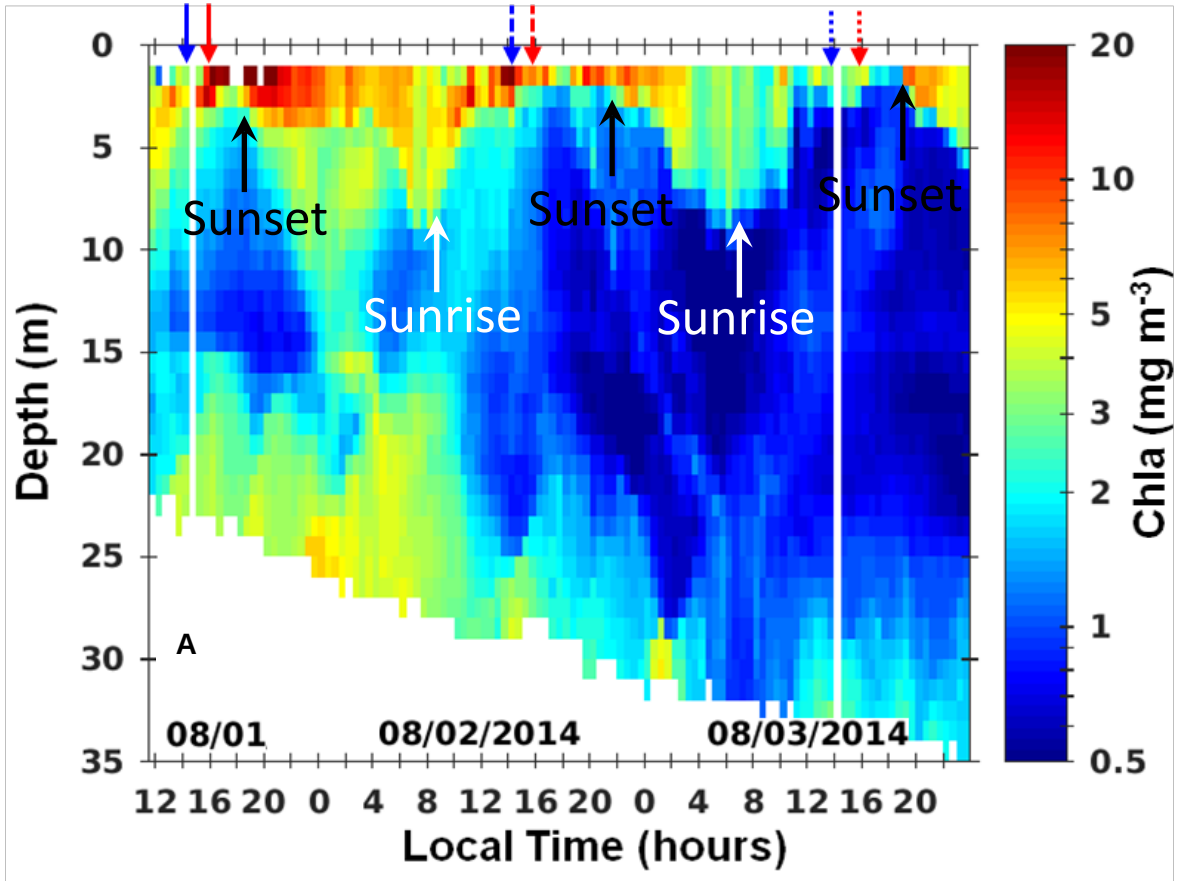
From Schofield et al. (2006, JGR)



VIIRS captures phytoplankton vertical migration in the NE Gulf of Mexico

Glider measurement from the same bloom shows thinner surface layer at 15:41 than at 14:00 within a diel cycle of *K. brevis* vertical migration (Hu et al., 2016)

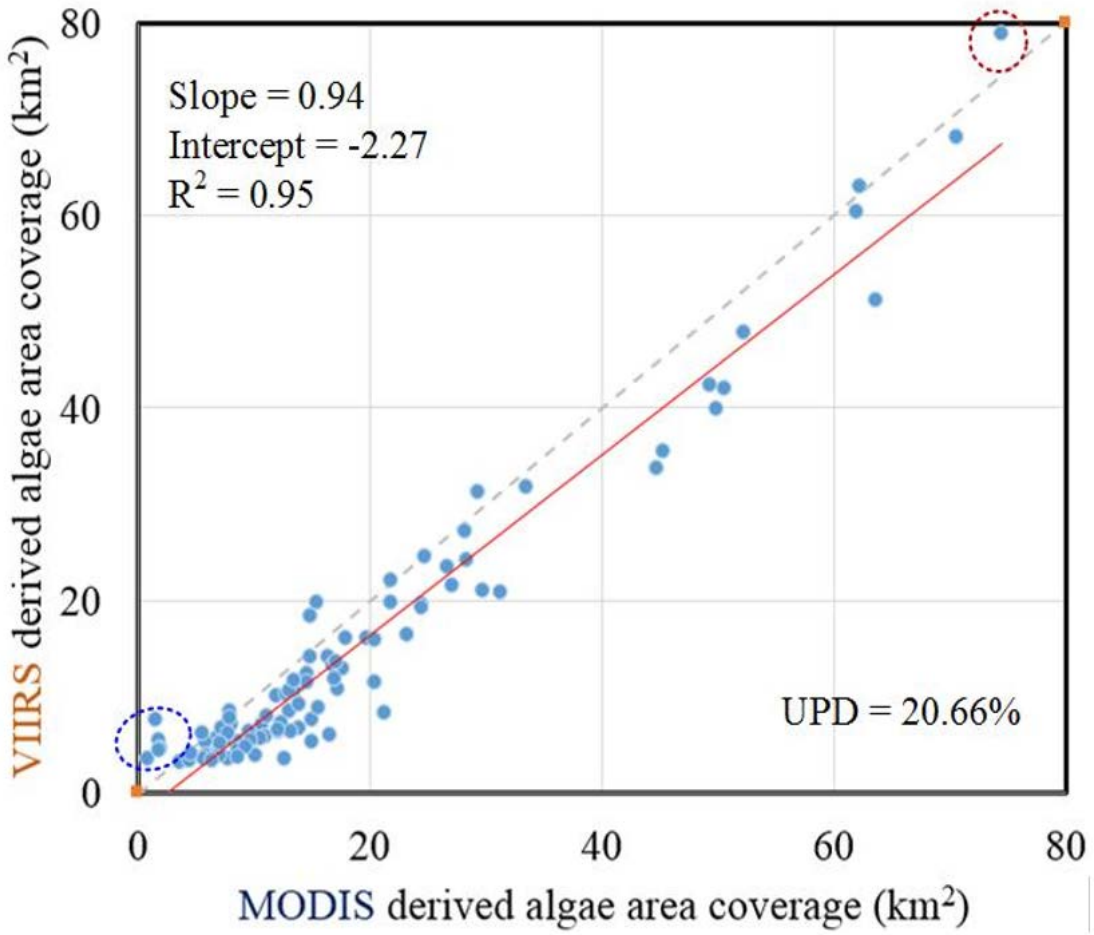
Blue: 14:00; red: 15:41



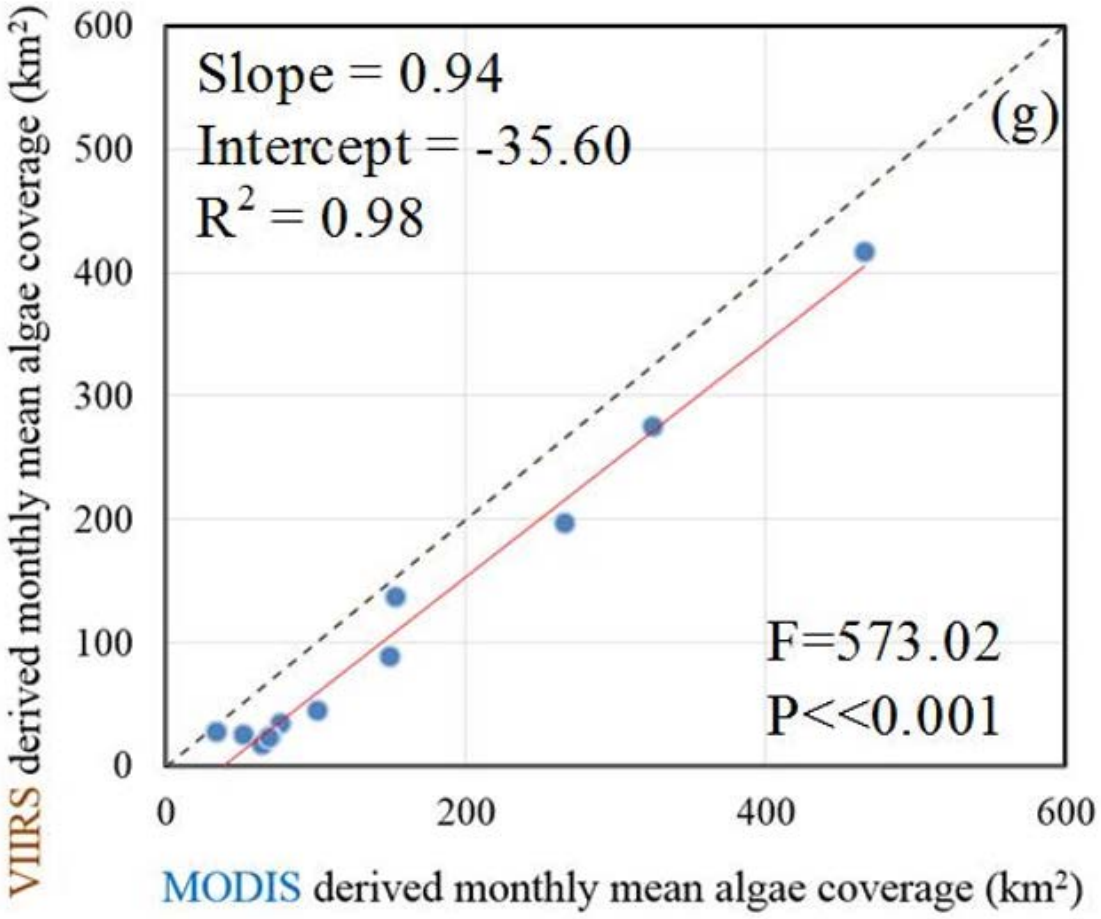
4. Application for floating macroalgae blooms

VIIRS continuity in monitoring floating macroalgae in the Atlantic

Algae coverage from simultaneous image pairs



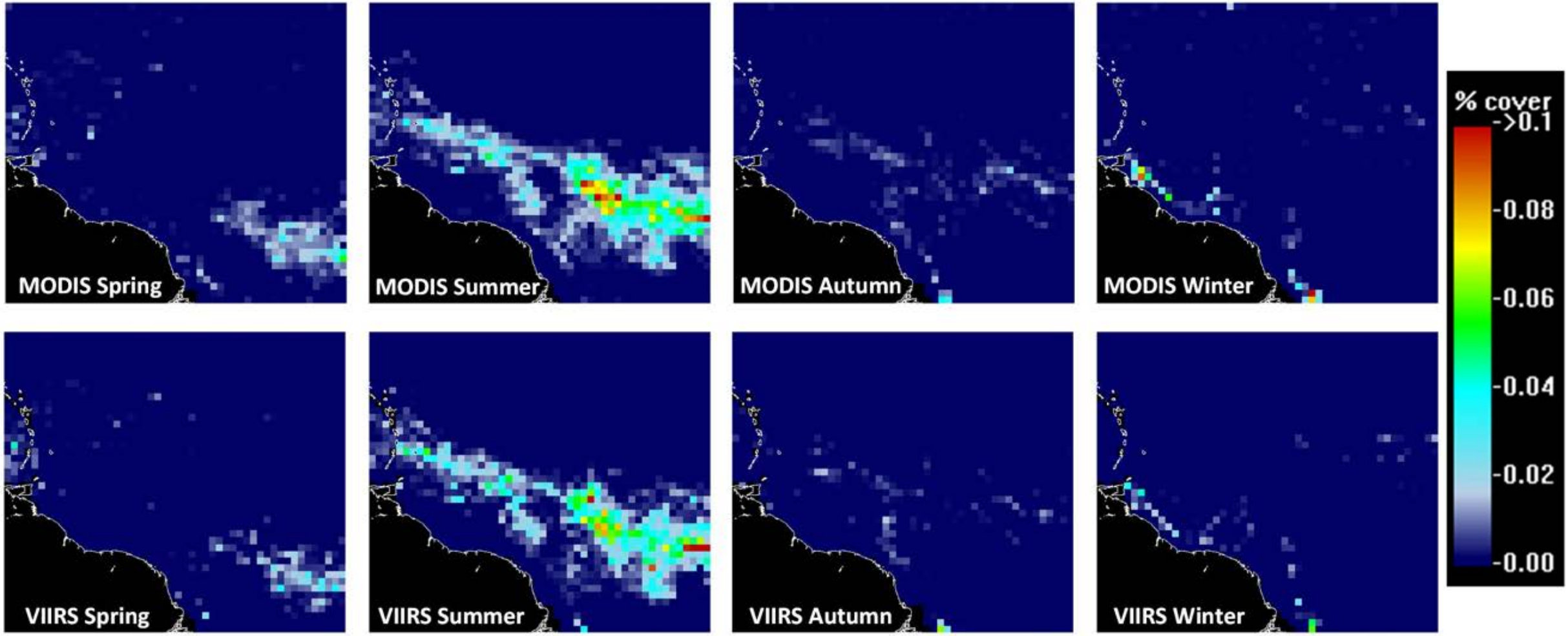
Algae coverage from monthly composites



From Wang and Hu (submitted)

VIIRS continuity in monitoring floating macroalgae in the Atlantic

Color represent mean surface density during 2016 for 0 – 22N, 63 – 38W



From Wang and Hu (submitted). 0.1 on the color scale means 0.1% instead of 10%

CONCLUSIONS

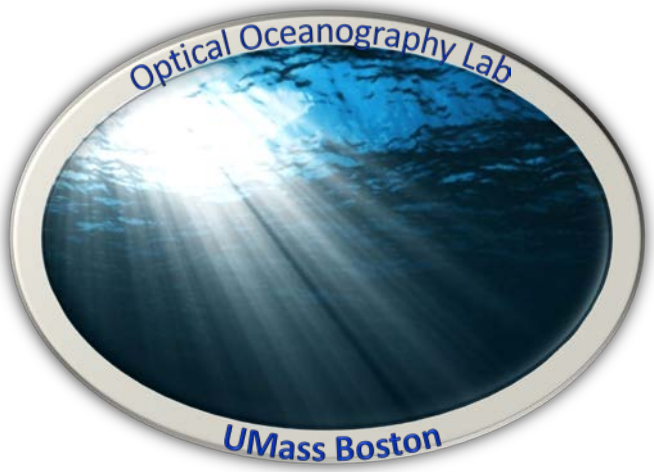
- Considering that ~40% of the open ocean and coastal match-ups pairs for the Gulf of Mexico were collected in shallow (z=3-8m), optically complex coastal waters with variable bottom types, the overall agreement between field and satellite $R_{rs}(\lambda)$ was impressive!
- For the Panhandle and Old Tampa Bay estuaries, performance degraded, but was still reasonable except for the 410-nm band.
- VIIRS observations of macroalgae slicks in global oceans were consistent with the MODIS data product
- VIIRS also showed unique capability to study short-term changes in surface harmful algal blooms
- The Rrs validation work is being summarized in a manuscript (Cannizzaro et al.), while other works have been published (Hu et al., 2016; Qi et al., 2017) or submitted (Wang and Hu).

Towards consistent VIIRS AOP and IOP products

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University of Massachusetts Boston

UMASS BOSTON



Acknowledgements:

NOAA/STAR

UMB activities:

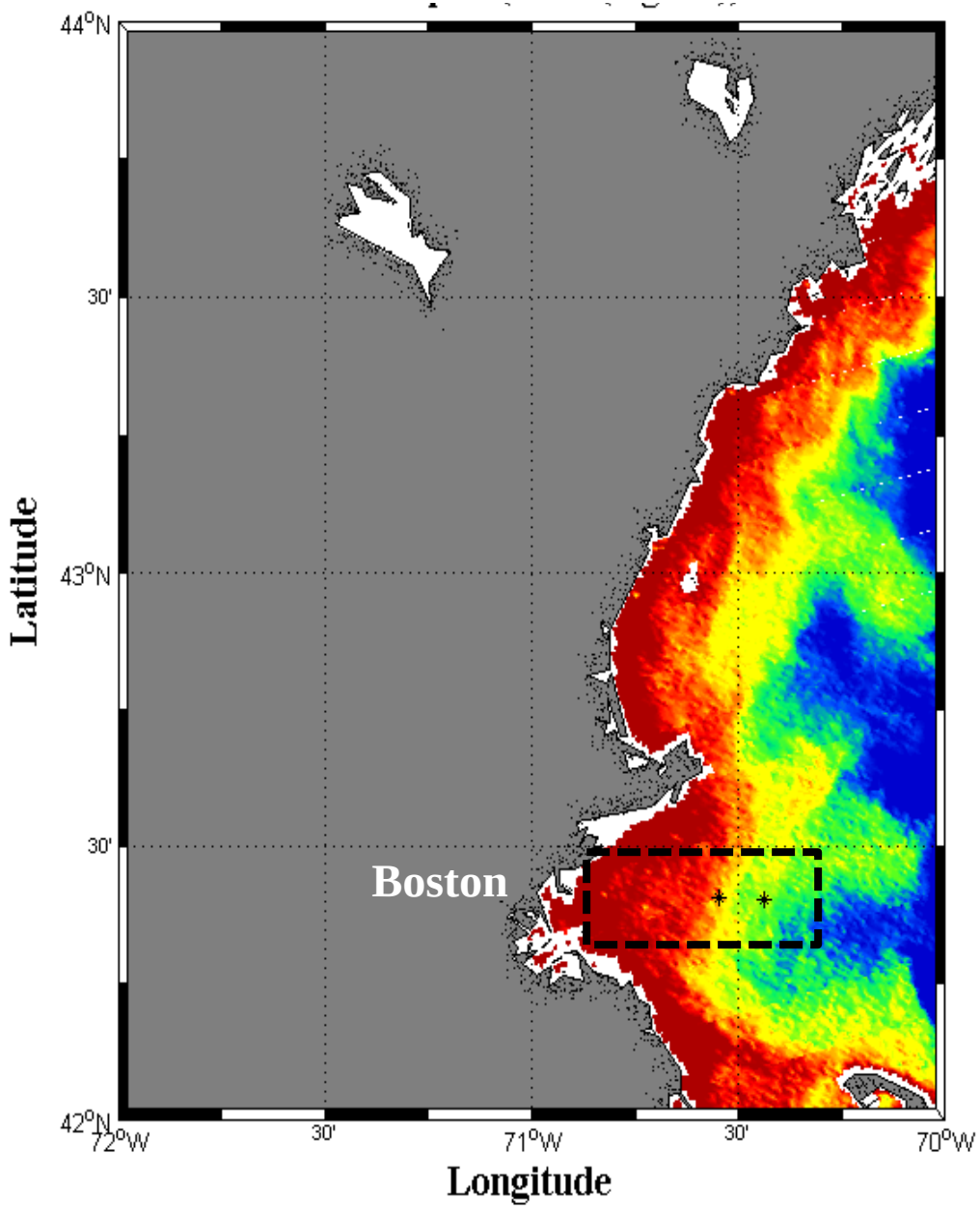
1. Evaluation of VIIRS Rrs products
2. Evaluation of VIIRS IOPs products
3. Some applications

1. Evaluation of VIIRS Rrs products

Data:
VIIRS CoastWatch L2, SBA Rrs

Measurements in Mass Bay:
Aug. 30, 2016 (1 match-up station);
Sep. 13, 2016 (2 match-up stations);
Sep. 15, 2016 (2 match-up stations);
Sep. 22, 2016 (5 match-up stations);
Feb. 2, 2017 (4 match-up stations);

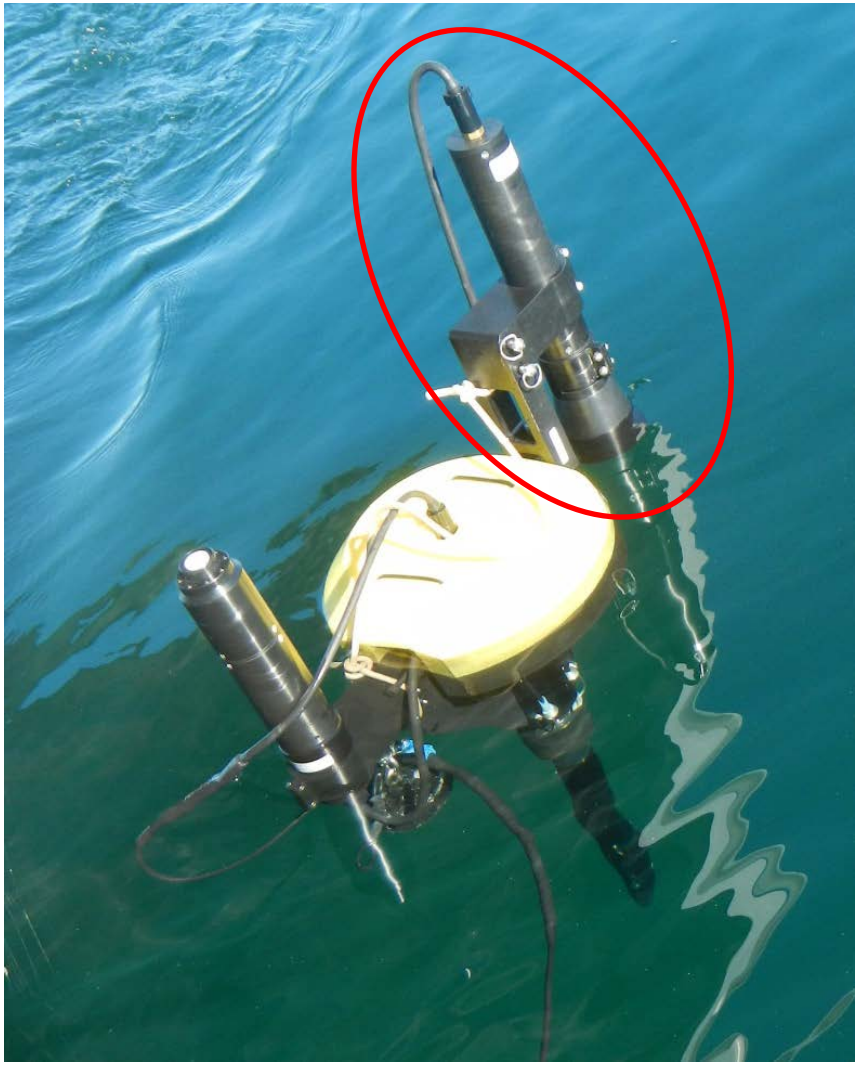
VIIRS cal/val cruise:
Oct. 13 – Oct. 18, 2016


44°N
30'
43°N
30'
42°N
72°W
30'
71°W
30'
70°W
Latitude
Longitude
Boston

SBA system to obtain accurate “ground truth” of Lw (Rrs)

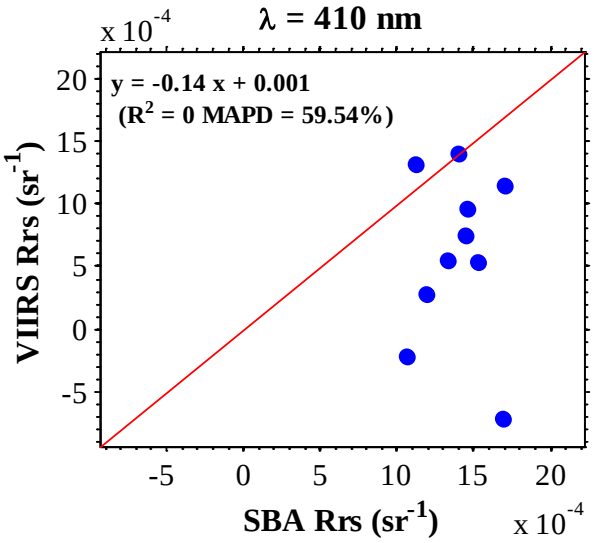


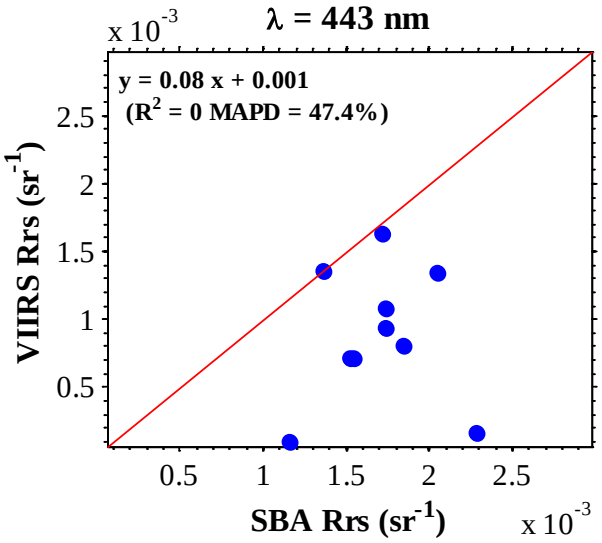


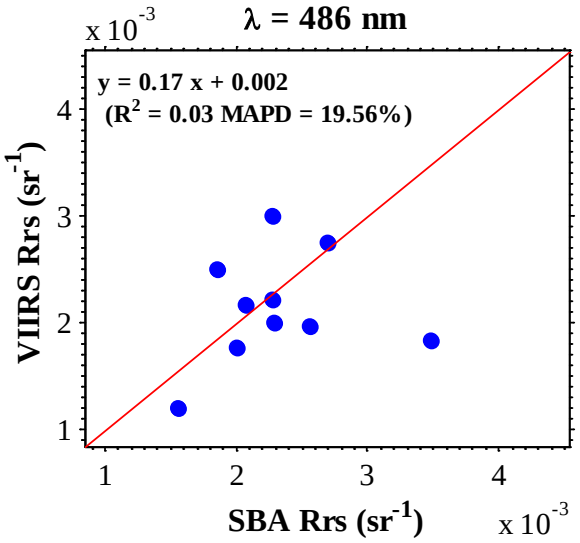


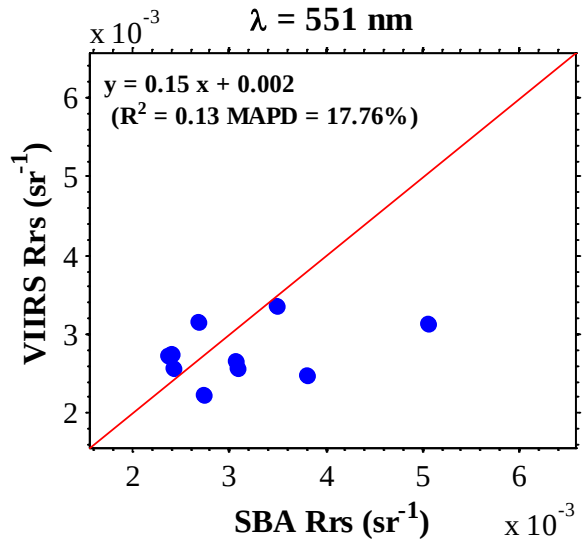
(Lee et al 2013)

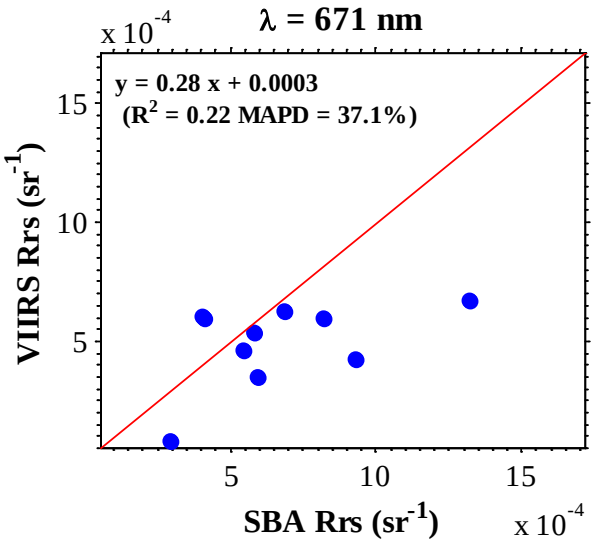
Comparison of Satellite Rrs data with Measurements in Mass Bay



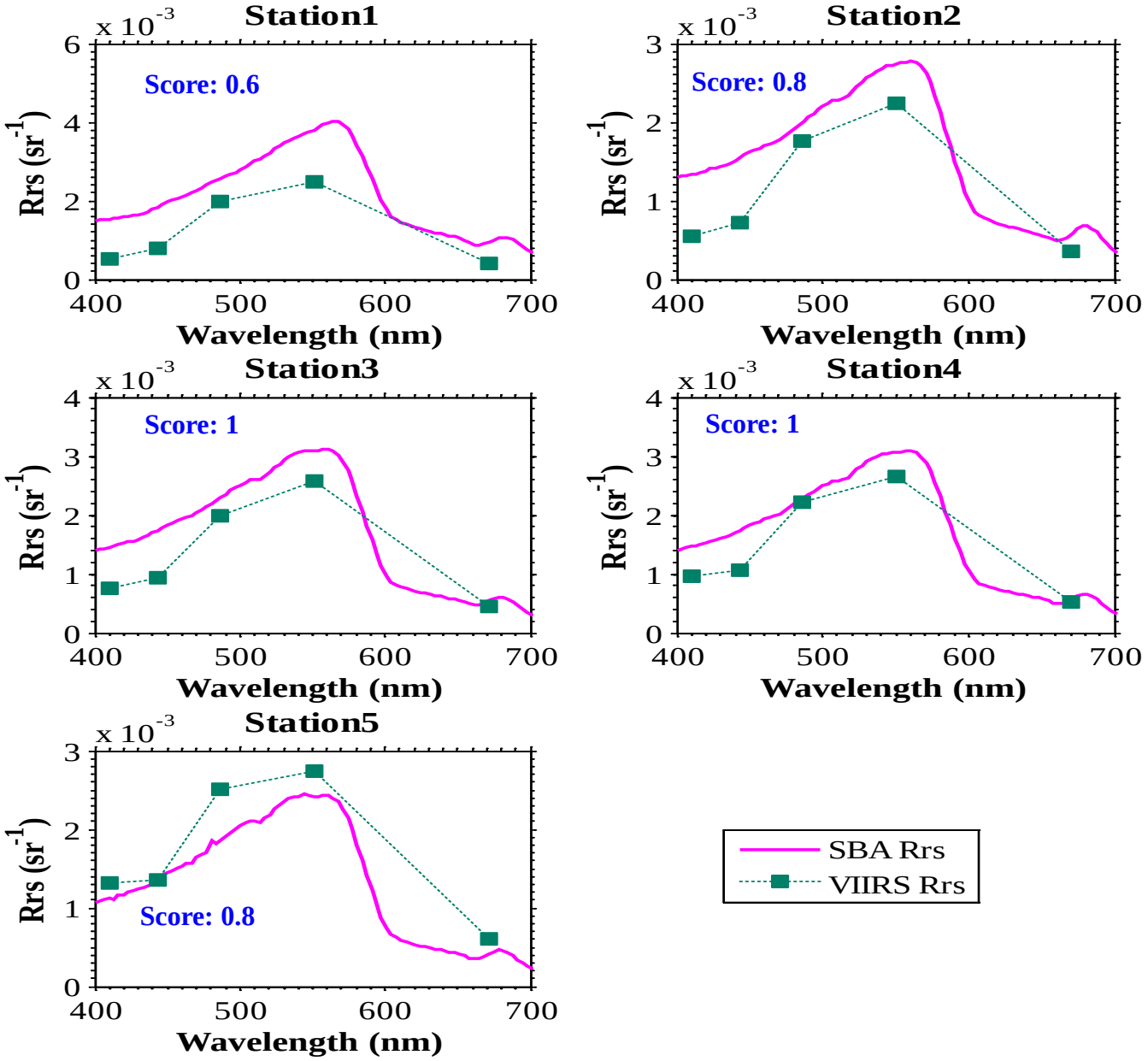




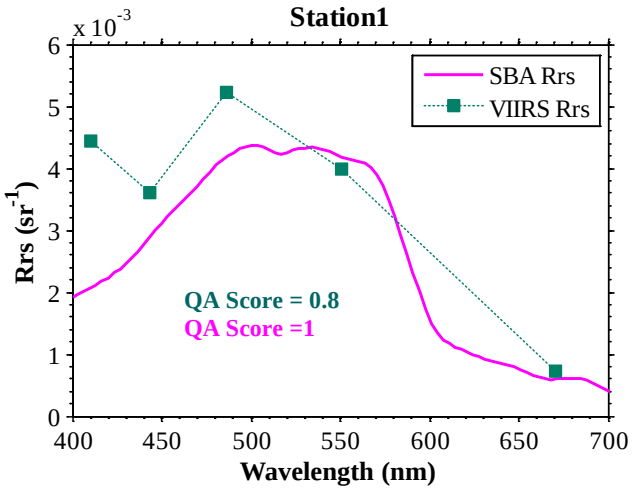


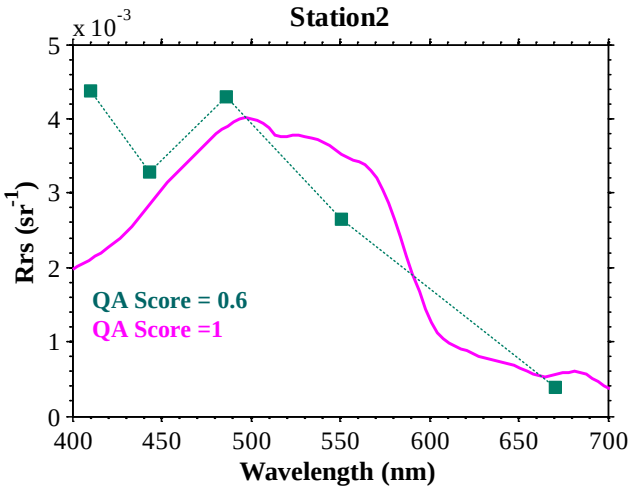


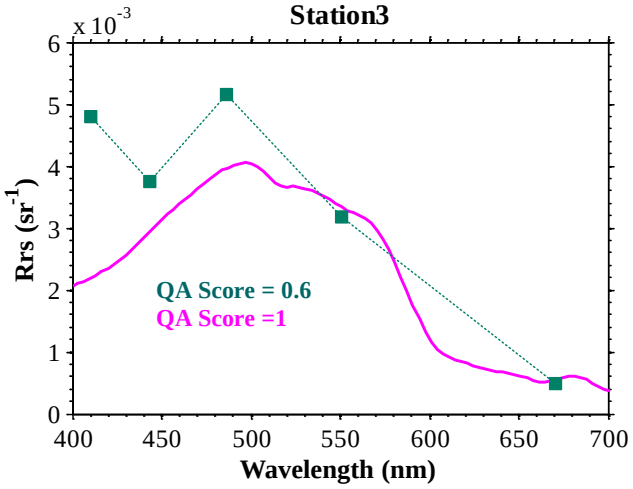
Examples of Rrs spectra

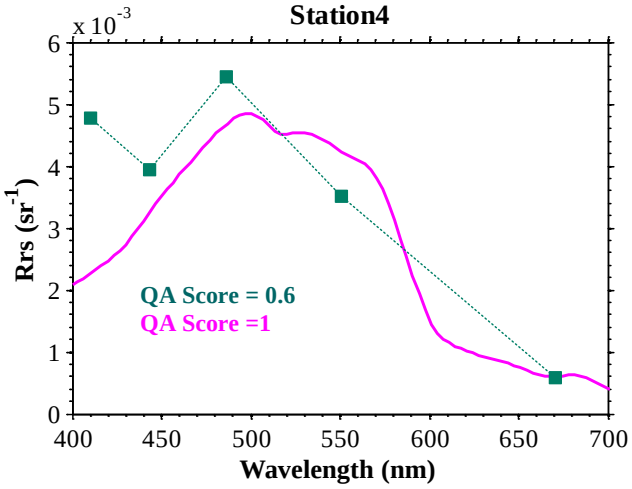


Examples of Rrs spectra (Feb. 2, 2017)

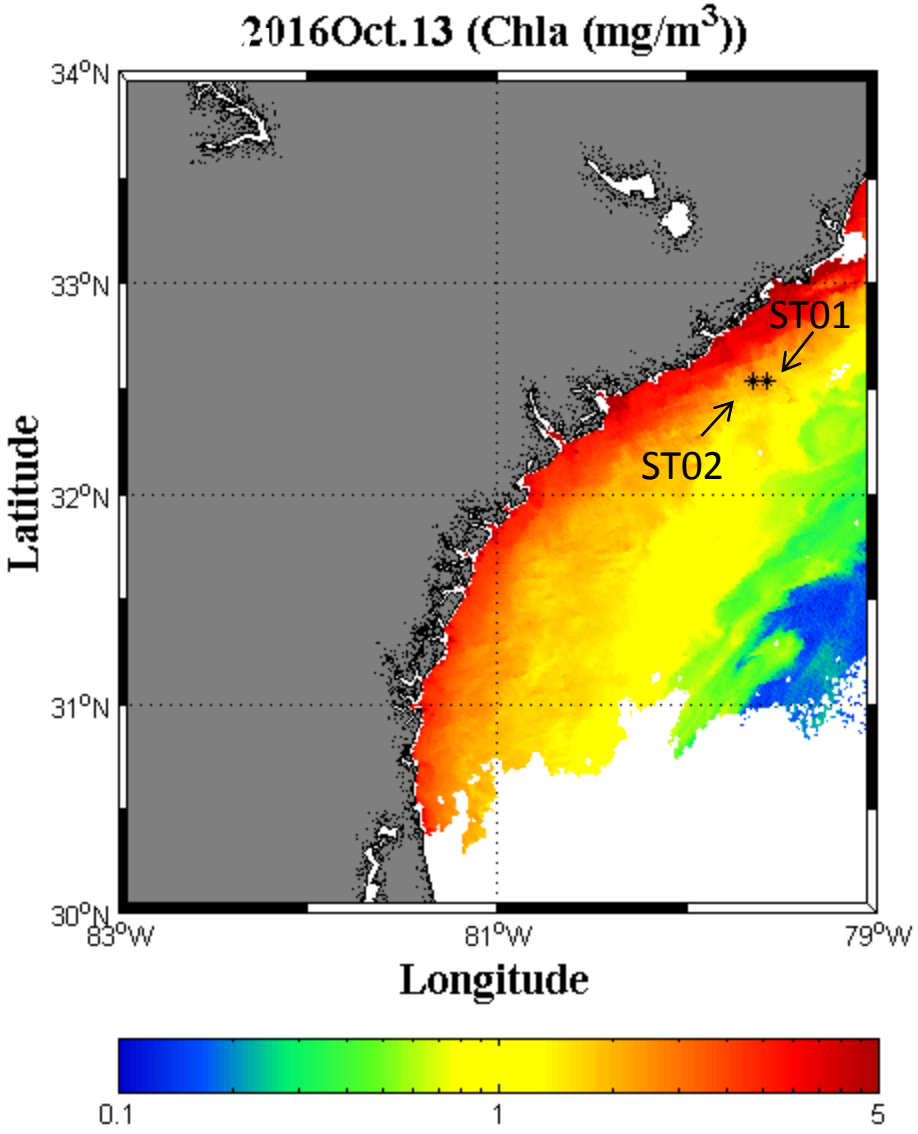


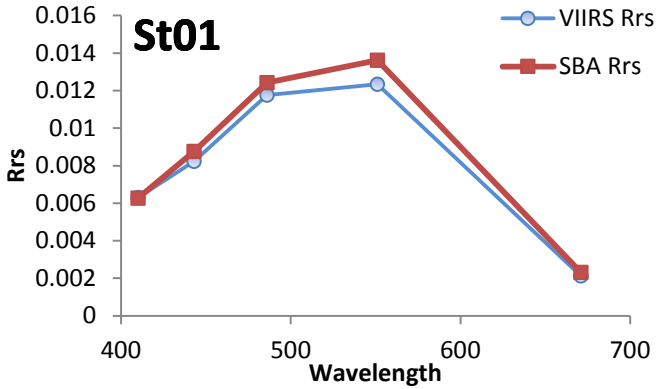


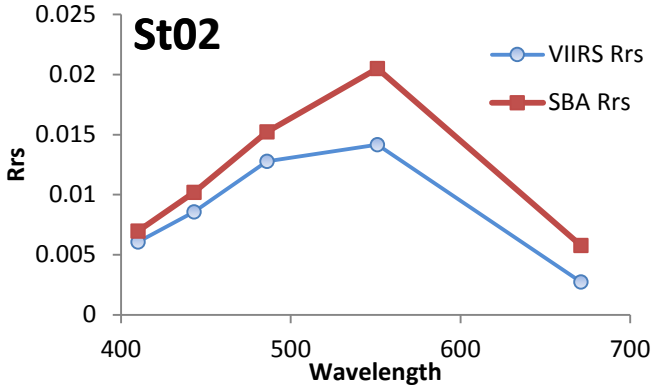




Examples of Rrs spectra (VIIRS cal/val cruise)







Part 1: Summary

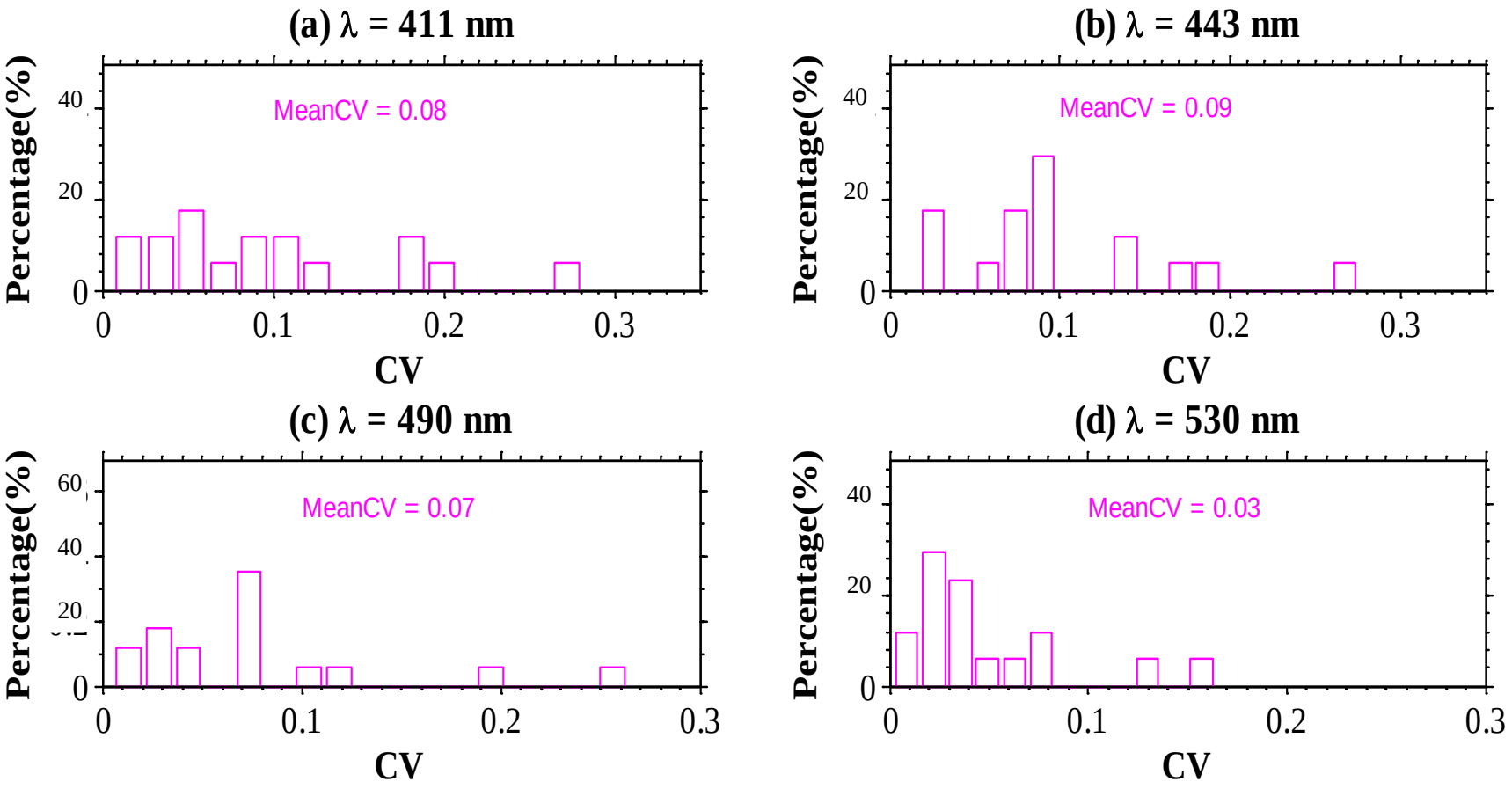
1. **For Massachusetts Bay, VIIRS Rrs data at shorter wavelengths (e.g. 410 nm) are always lower than field measurements.**
2. **QA score is a good indictor of the quality of satellite Rrs data. Satellite Rrs data with higher scores agree better with field measurements .**
3. **For most matchup stations during the 2016 VIIRS cruise, NOAA VIIRS Rrs data agree well with field measurements.**

2. Evaluation of VIIRS IOPs products

Commonly, measurements from ACS (or AC9) and BB9 (HS6) are considered the "ground truth" of IOPs in field.

How good are the "ground truth" of IOPs?

An example of uncertainties of ACS measurements from the 2014 VIIRS cruise (two ACSs for each station)



A scheme to obtain reliable IOPs in situ: R_{rs}&K_d

$$r_{rs}(\Omega) = \left(G_0^w(\Omega) + G_1^w(\Omega) \cdot \frac{b_{bw}}{a + b_b} \right) \frac{b_{bw}}{a + b_b} + \left(G_0^p(\Omega) + G_1^p(\Omega) \cdot \frac{b_{bp}}{a + b_b} \right) \frac{b_{bp}}{a + b_b}$$

(Lee et al 2004)

$$K_d = (1 + m_0 \cdot \theta_s) \cdot a + \left(1 - \gamma \cdot \frac{b_{bw}}{b_b}\right) \cdot m_1 \cdot \left(1 - m_2 \cdot e^{-m_3 \cdot a}\right) \cdot b_b$$

(Lee et al 2013)

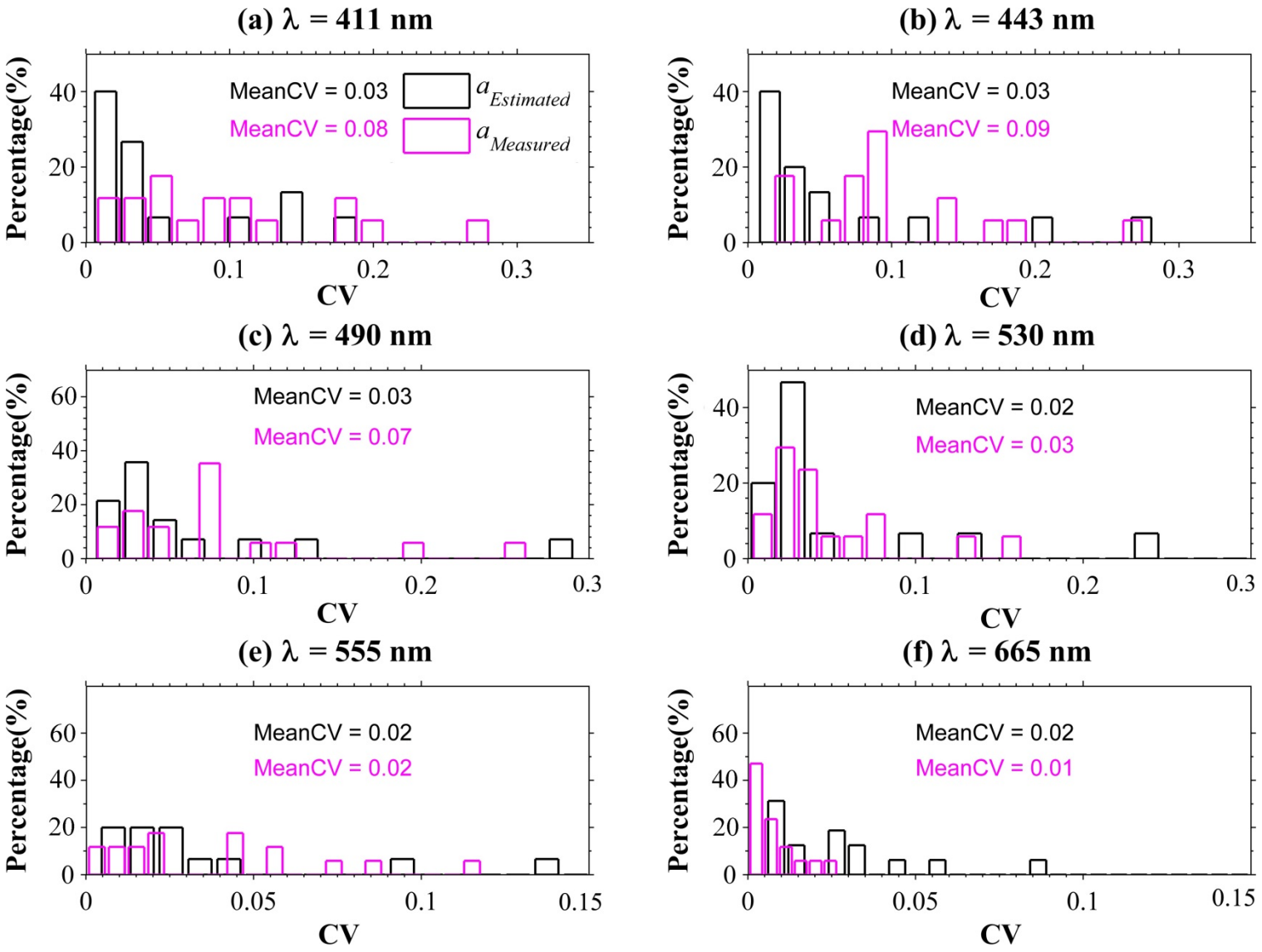
$$\Rightarrow \quad a(\lambda), b_b(\lambda)$$

Advantages:

(1). We can obtain hyperspectral absorption and backscattering coefficients;

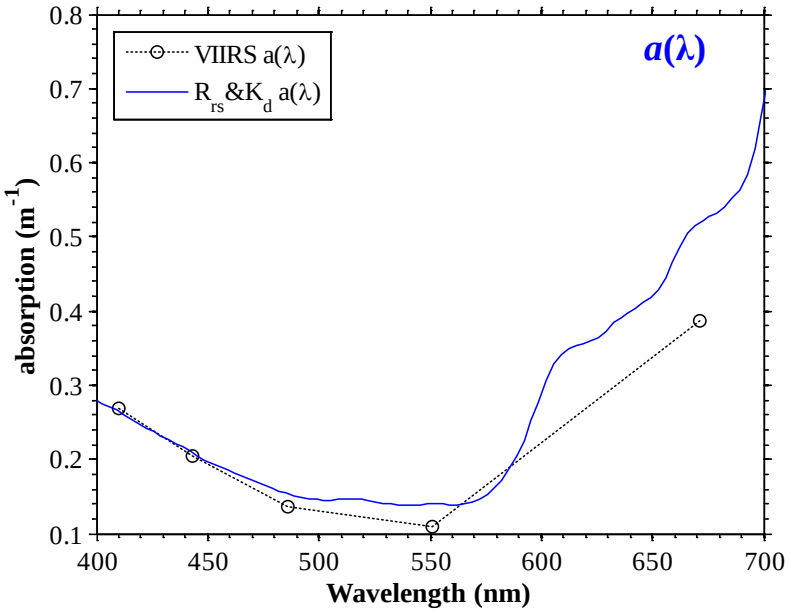
(2). With more casts (~5-15 casts for each station) of HyperPro, we can obtain more reliable absorption and backscattering coefficients of water.

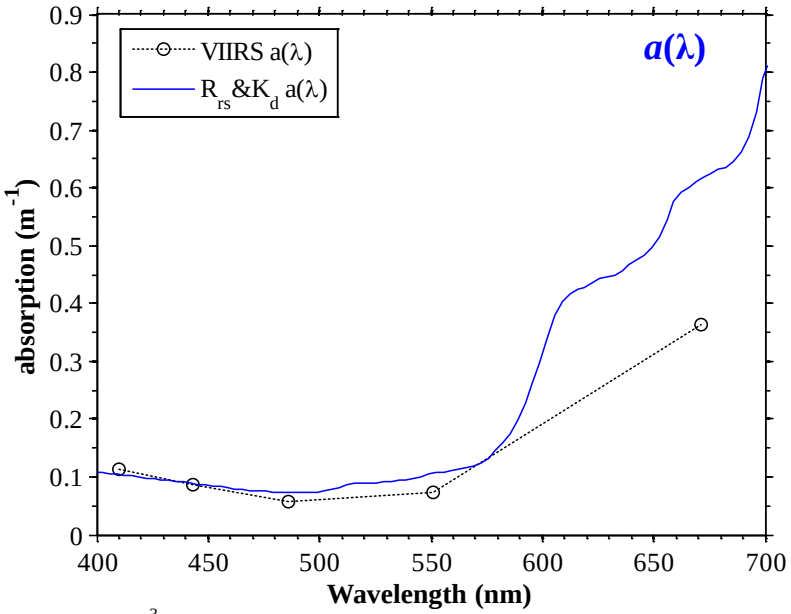
Comparison of uncertainties of absorption from Rrs&Kd and ACSs

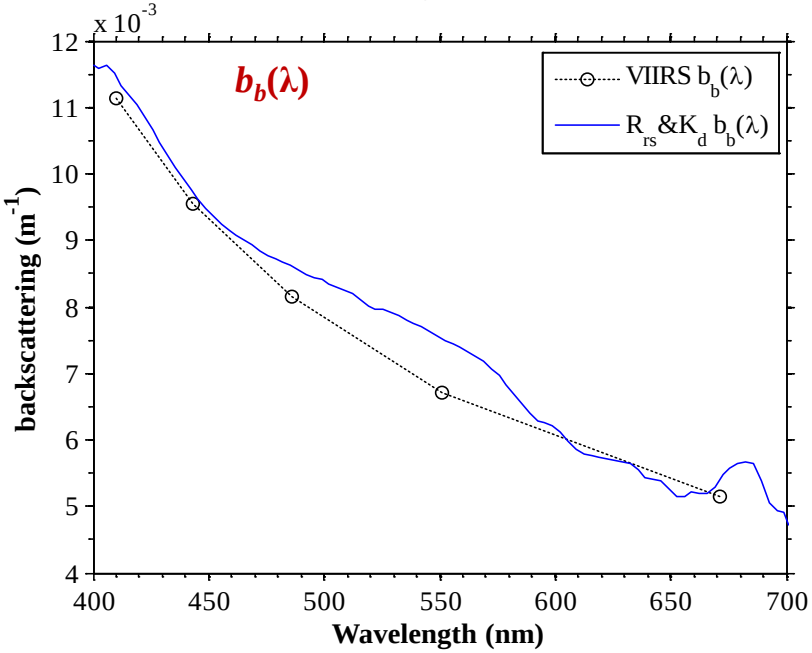


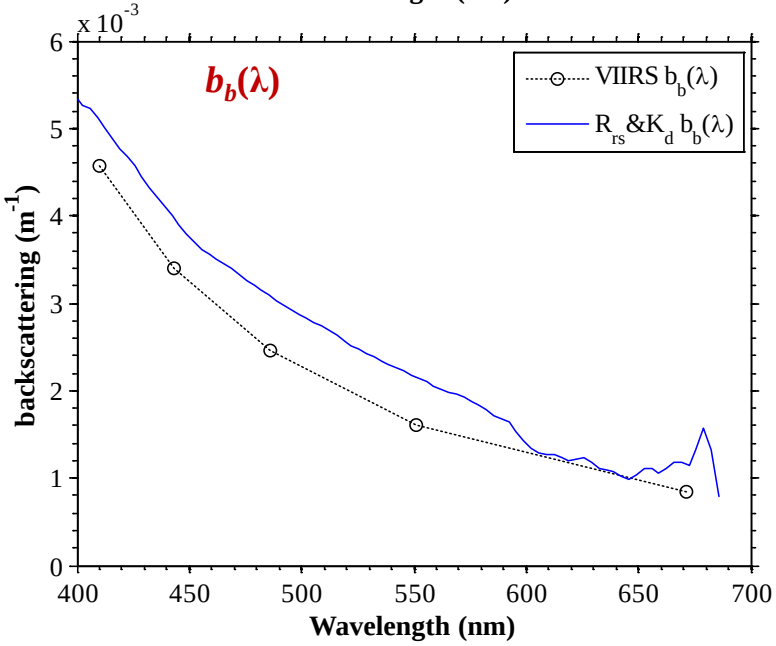
Validation of VIIRS IOPs products (VIIRS 2014 cruise)

Examples of IOPs spectra



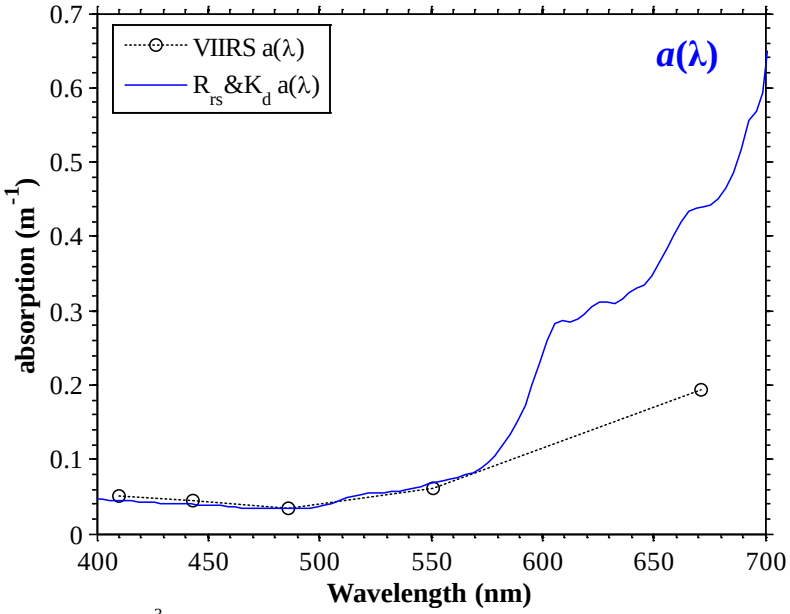


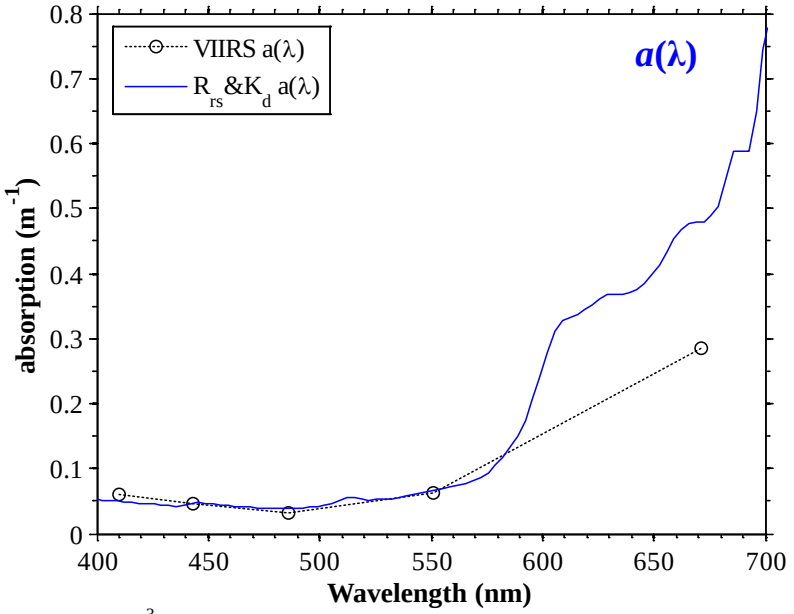


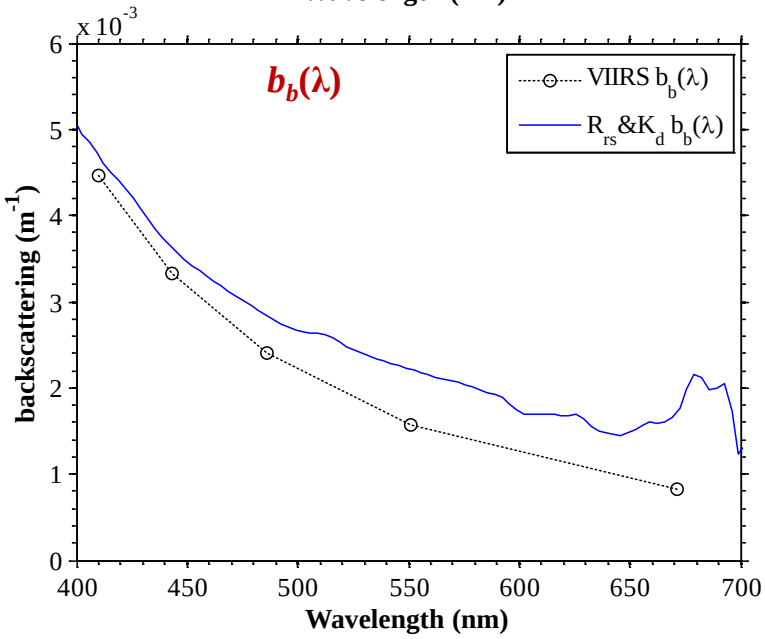


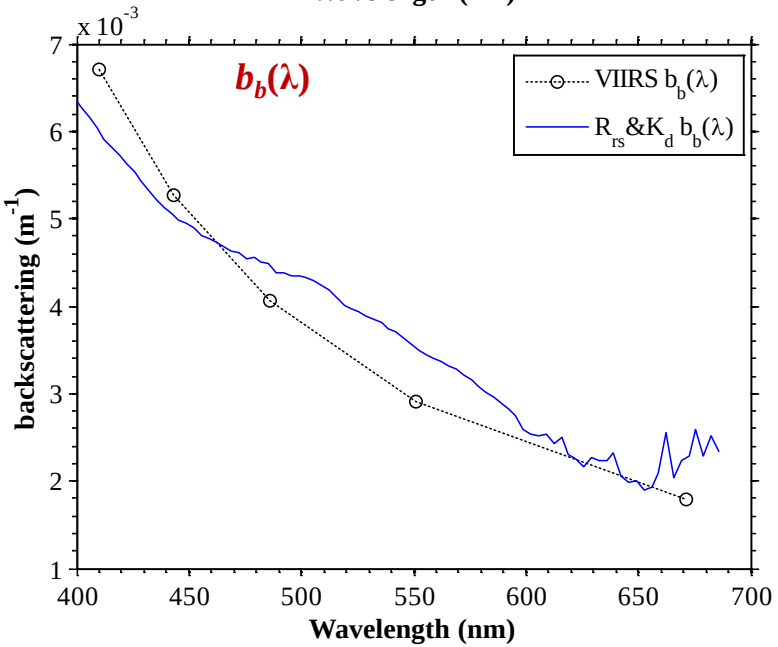
Validation of VIIRS IOPs products (VIIRS 2015 cruise)

Examples of IOPs spectra

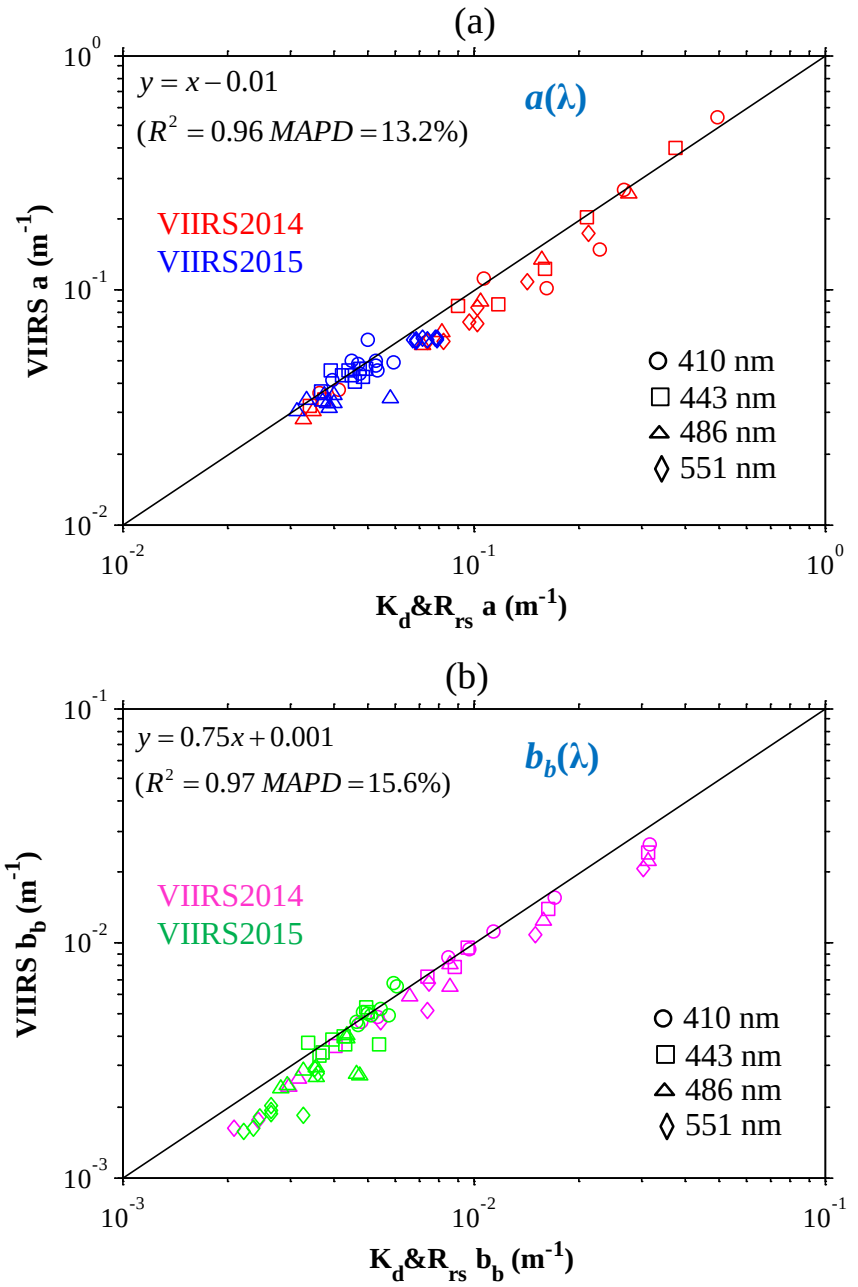








R_{rs}&K_d IOPs vs VIIRS IOPs (VIIRS cruises 2014&2015)



Part 2: Summary

(1). With multiple casts of ACS and HyperPro measurements, it is found that the derived hyperspectral a and b_b from R_{rs}&K_d are with lower uncertainties when compared with those from the presently used ACS system.

(2). Validation of IOPs during the VIIRS cruises (2014 and 2015) shows that the VIIRS IOPs by QAA are generally consistent with in-situ IOPs.

Phytoplankton and particles from IFCB



1) Submersible

2) Taking photos of phytoplankton cells

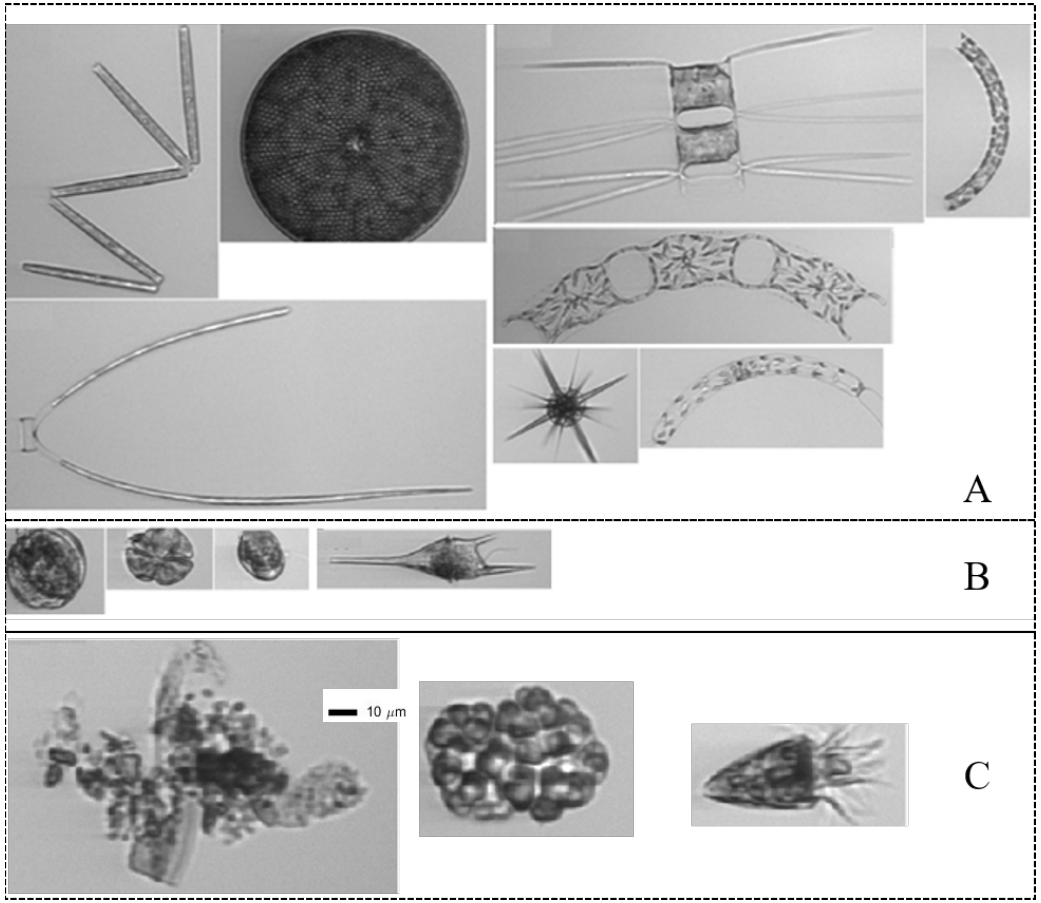
3) Sensible size range: <10 to 100 μm (~1 μm resolution)

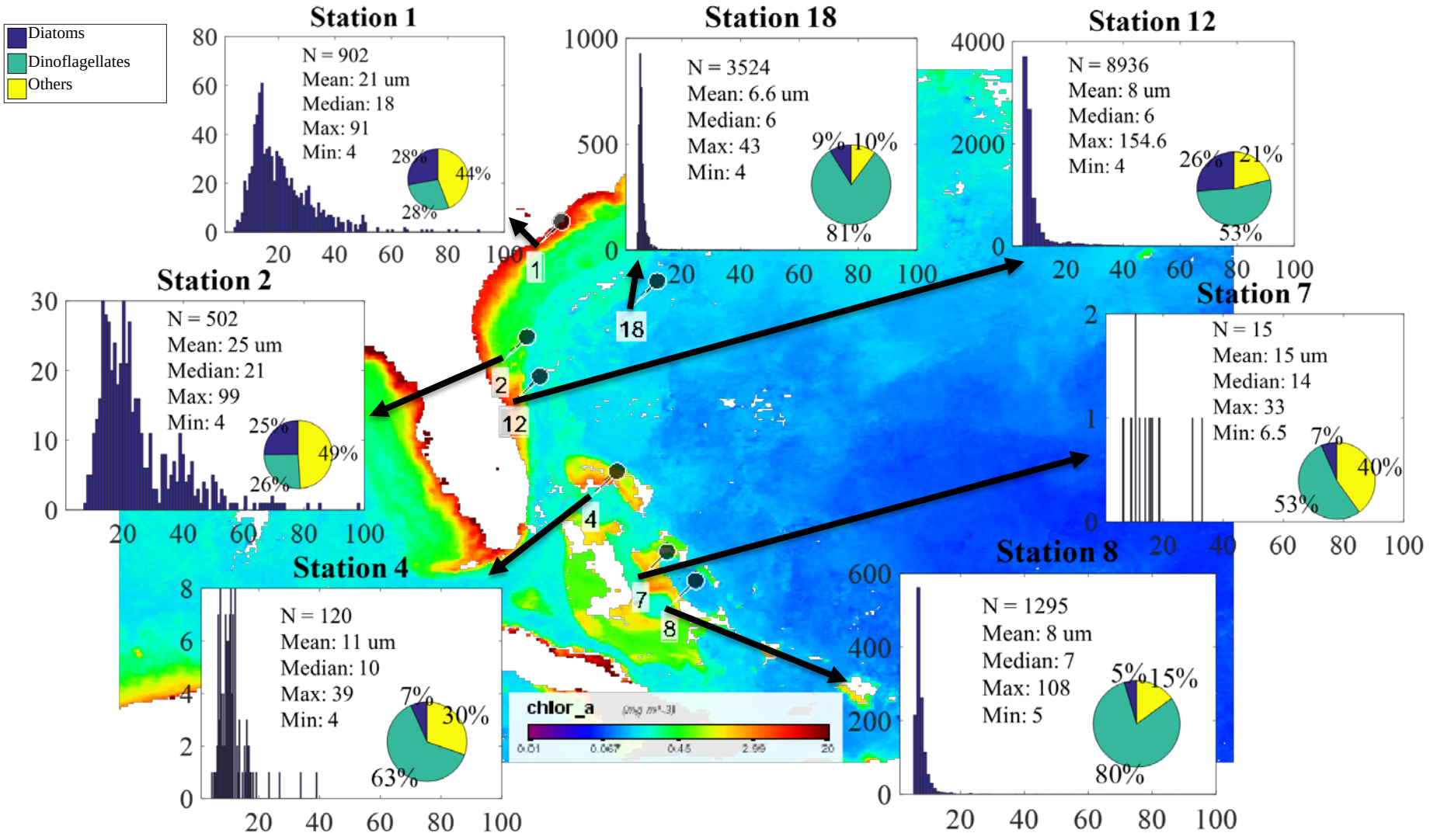
Different species recorded by IFCB for two dominant phytoplankton groups:

A: diatoms,

B: dinoflagellates,

C: others

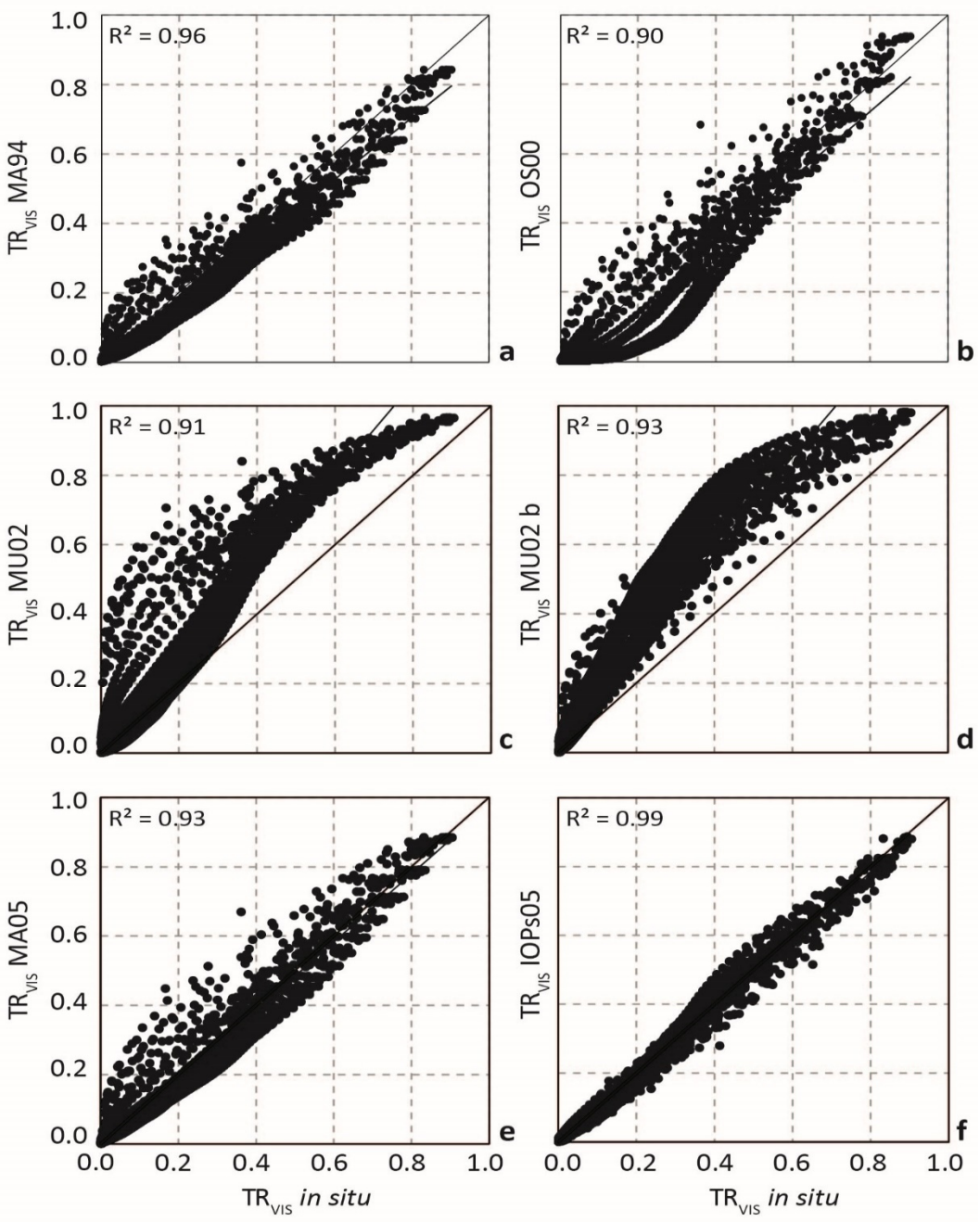



Diatoms
Dinoflagellates
Others
Station 1
N = 902
Mean: 21 um
Median: 18
Max: 91
Min: 4
28%
44%
28%
Station 18
N = 3524
Mean: 6.6 um
Median: 6
Max: 43
Min: 4
9%
10%
81%
Station 12
N = 8936
Mean: 8 um
Median: 6
Max: 154.6
Min: 4
26%
21%
53%
Station 2
N = 502
Mean: 25 um
Median: 21
Max: 99
Min: 4
25%
49%
26%
Station 7
N = 15
Mean: 15 um
Median: 14
Max: 33
Min: 6.5
7%
40%
53%
Station 4
N = 120
Mean: 11 um
Median: 10
Max: 39
Min: 4
7%
30%
63%
Station 8
N = 1295
Mean: 8 um
Median: 7
Max: 108
Min: 5
5%
15%
80%
chlor_a
1
18
2
12
4
7
8

3. Some applications

A. How good is solar transmission estimated from remote sensing?

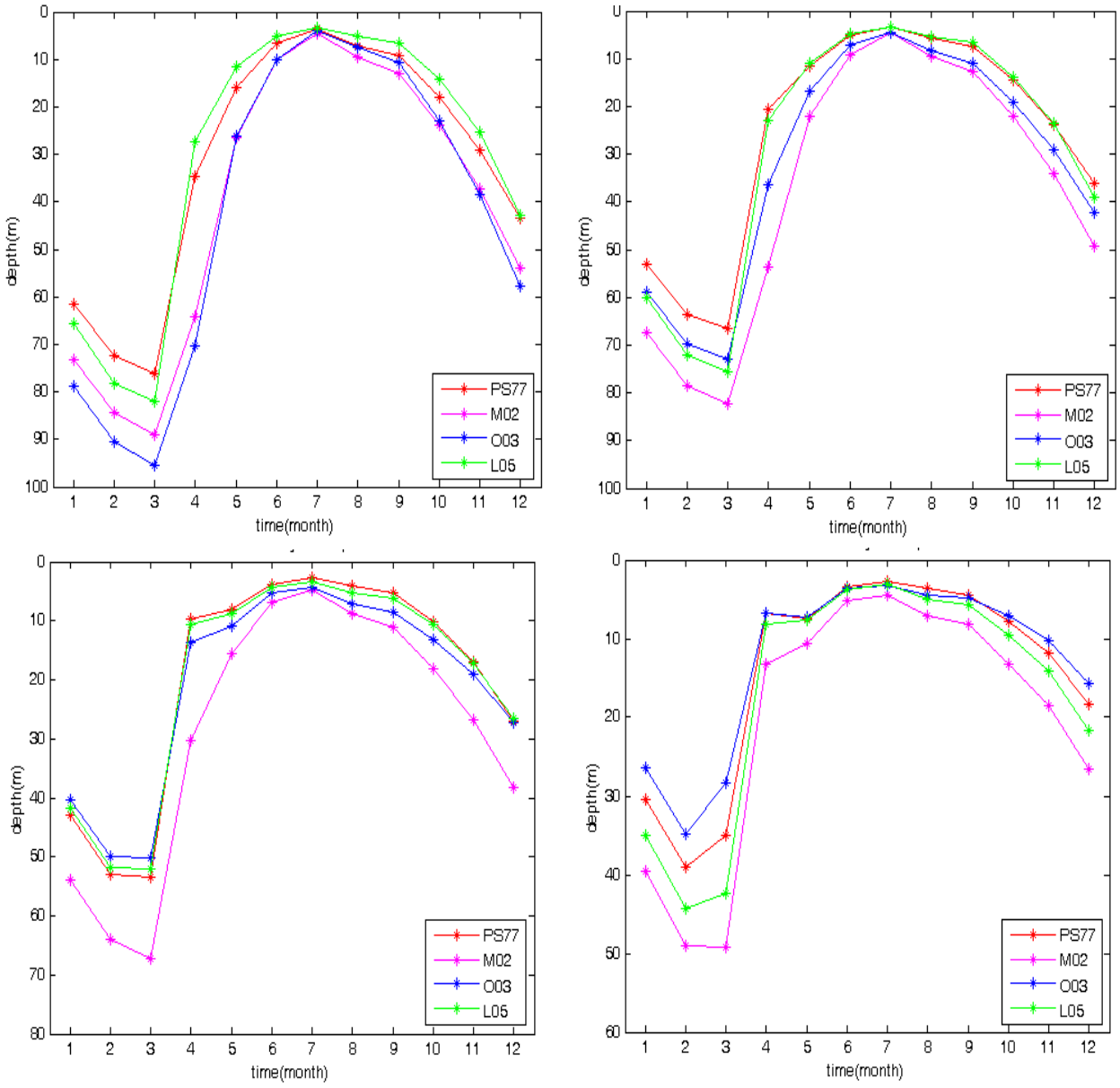
B. How big is the impact of modeled solar transmission based on remote sensing on upper column T and MLD?



A. How good is solar transmission estimated from remote sensing?

(see Laura's poster)

Mixed-layer depth with the different trans. models (all from the same Rrs)



B. How big is the impact of modeled solar transmission based on remote sensing on upper column T and MLD?

(see Liu's poster)

Thank you!

USC-OSU VIIRS Cal/Val 2017

STAR JPSS Annual Science Meeting
14-18 August 2017, College Park, MD

Matthew Ragan, USC
Ivan Lalovic, Nick Tufillaro, OSU

Outline

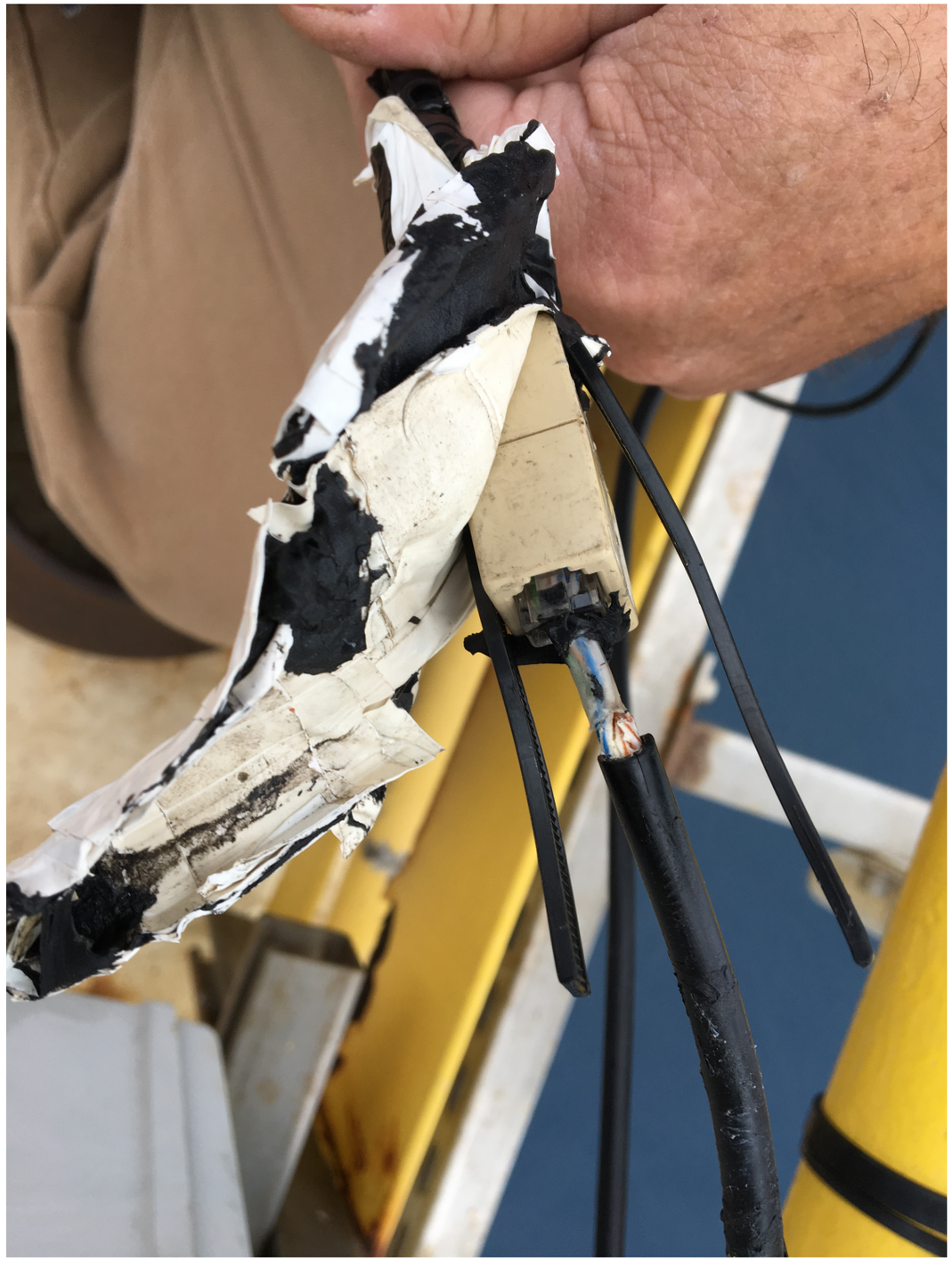
- Platform Eureka Operation
- Side by Side SeaPRISM Comparisons
- NOAA Cruise
  - Spectral Evolution Rrs automation with uncertainties
  - Plaque Comparisons
- Current Work: Eureka Cruise Fall 2017


Lomita
Signal Hill
Palos Verdes Estates
Long Beach
Orange
Garden Grove
Rancho Palos Verdes
CA-47
Westminster
Santa Ana
Tustin
Seal Beach
Los Angeles
Fountain Valley
Huntington Beach
Irvine
Costa Mesa
Newport Beach
Oil Platform Eureka
USC-OSU SeaPRISM Site
Laguna Beach
Santa Catalina Island
Avalon

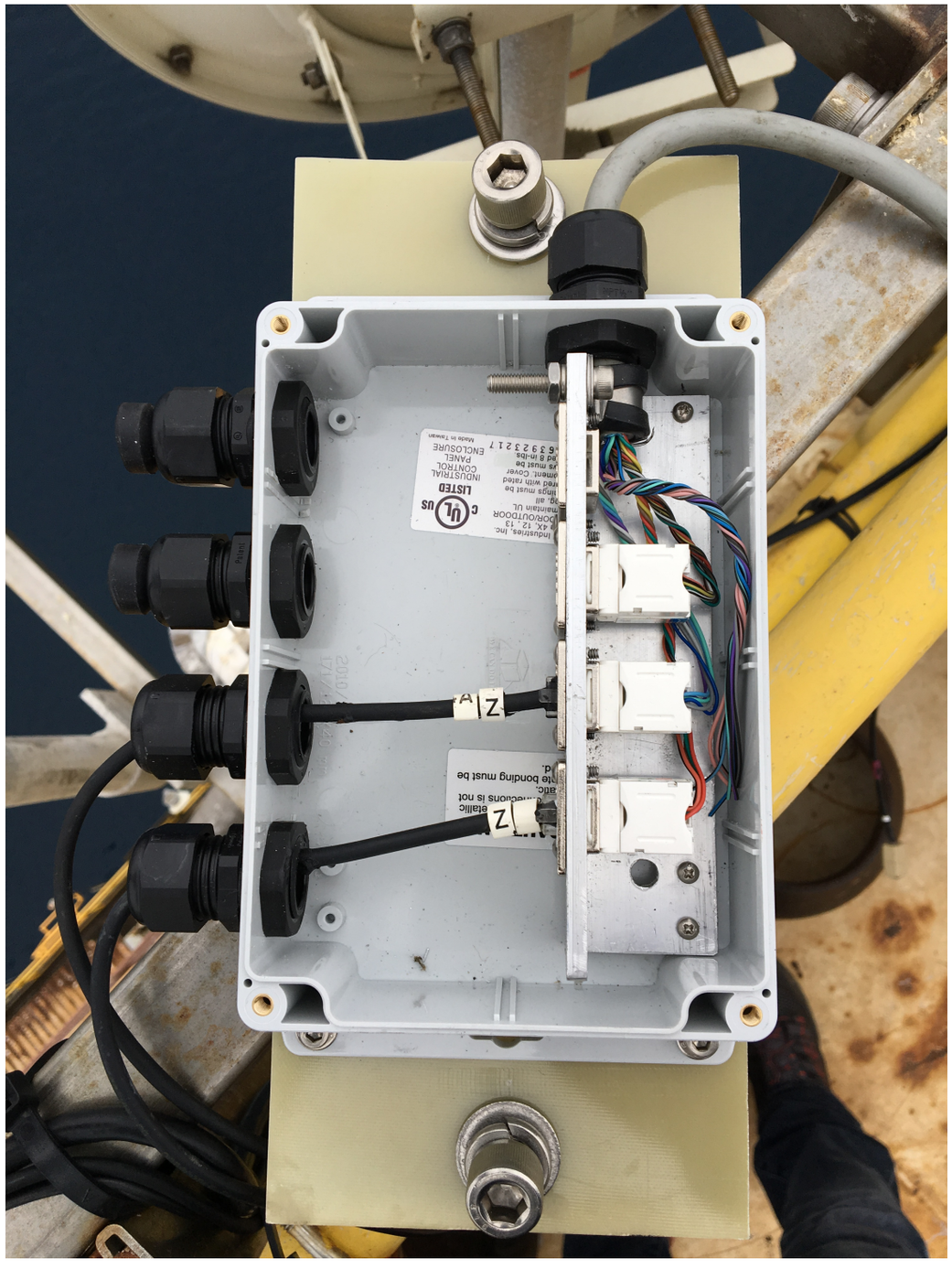
Infrastructure Upgrades at Platform Eureka

RJ-12 Coupler with self vulcanizing putty and electrical tape





NMEA Box with RJ-12 Keystone connector and cable gland





Side-by-side SeaPRISM Comparison

1 September —> 31 December 2016
119 Matches

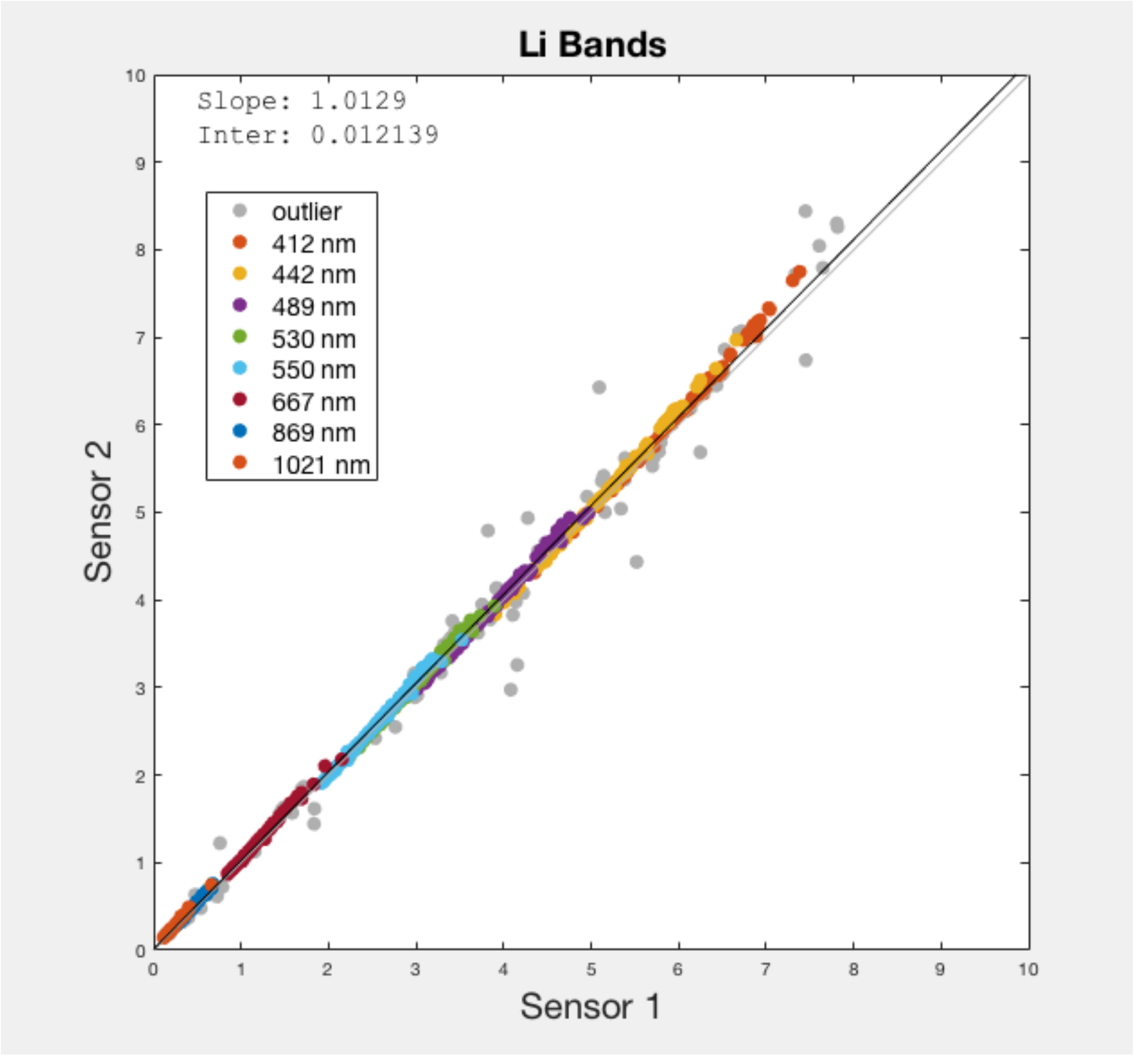
SeaPrism_2 Removed 5 December 2017

Outlier Rejection

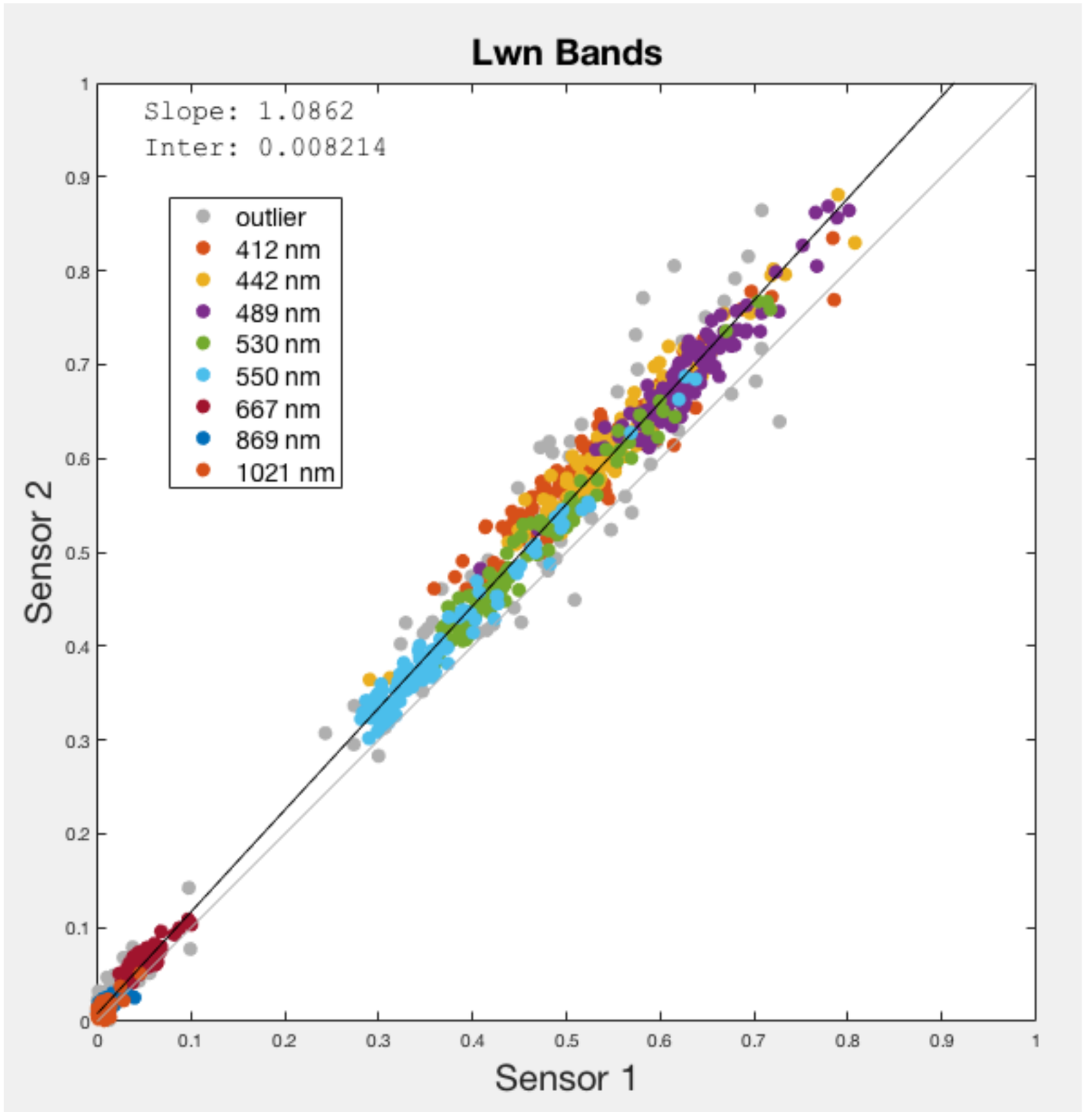
Remove 10% (12 points out of 119) of data
with largest difference from initial linear regression

SeaPrism 1: Instrument 612
SeaPrism 2: Instrument 058

Sky Radiance Sensor Comparisons (Regression on All Bands)



Normalized Water Leaving Radiance Sensor Comparisons (Regression on All Bands)



Notes

Outlier rejection effect is minimal (but still good practice)

Sky Radiance provides (rough) estimate of ‘instrument’ noise and bias.

Water leaving radiance provides (rough) estimate of ‘processing’ noise and bias.

Sensors show a ‘difference’ of ~10% in field, but ‘stable’ (a stable bias over time) that is easily corrected with a ‘vicarious’ — field based, band-by-band — adjustment.

Working on paper comparing ‘field’ variances to 'lab' cal variances.

Cal/Val Cruise 2016 (Hurricane Matthew)

— *SPECTRAL EVOLUTION and HyperPro DATA COLLECTION*





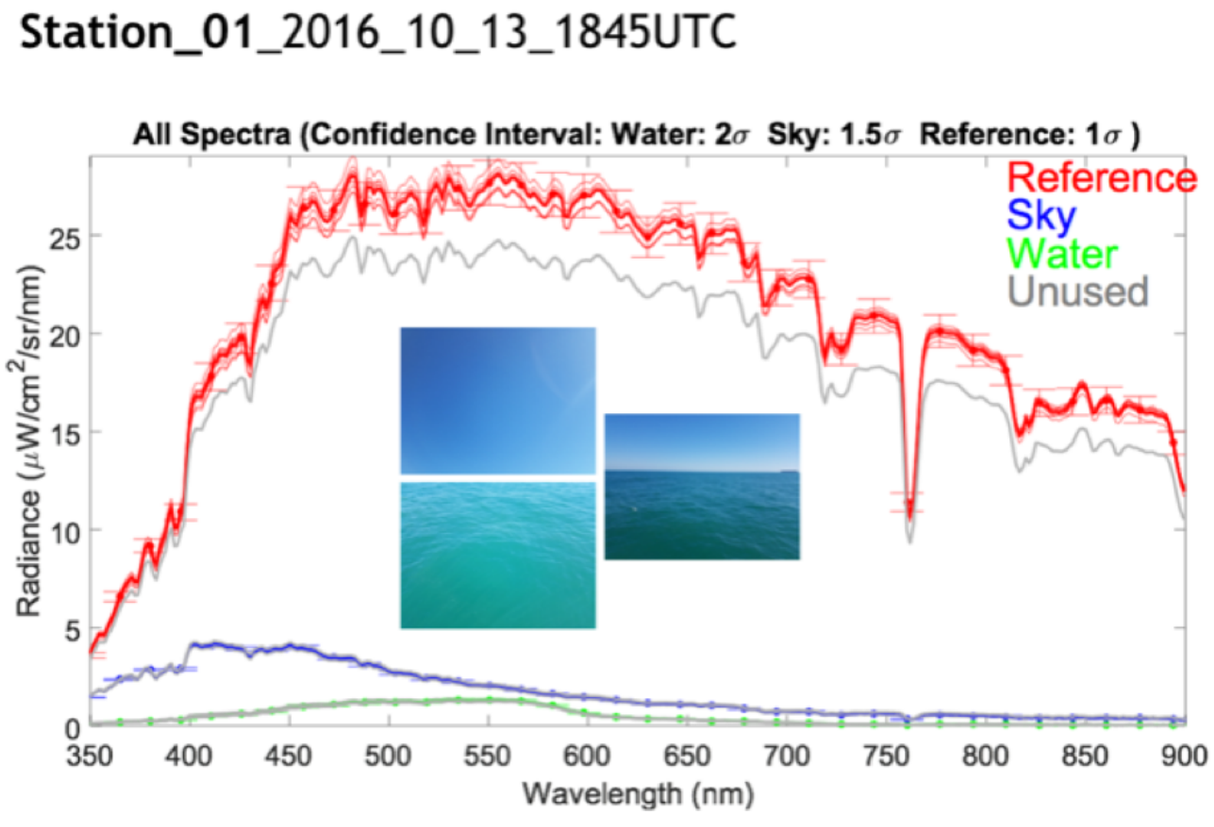
http://www.spectralevolution.com/lightweight_portable_battery_operated_spectrometer.html

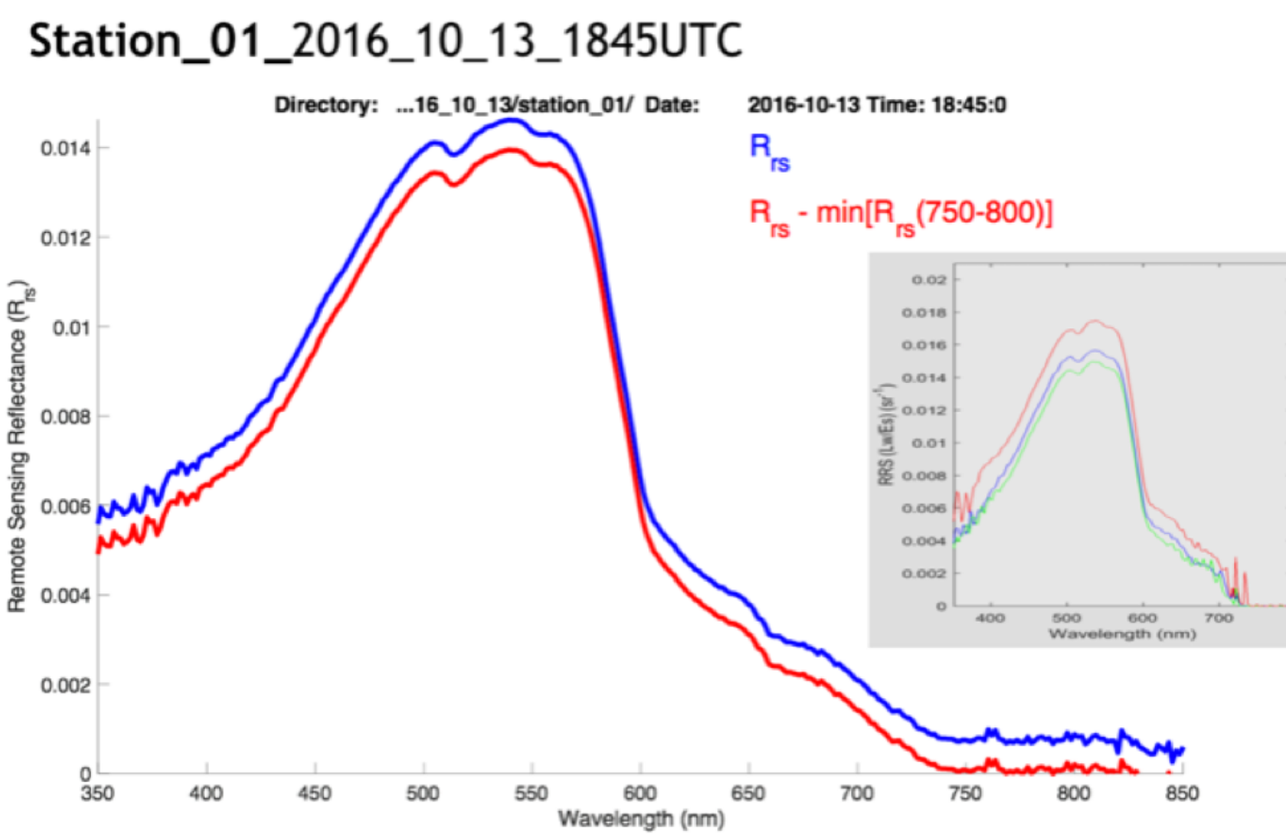
STATION	Date and UTC Time	LAT / LONG	Decimal Degrees	NOTES
1	10/13/2016	LAT	32.6223	Trychodesmium
	1845	LONG	-79.5790	
2	10/13/2016	LAT	32.5797	Trychodesmium
	2125	LONG	-79.6480	
3	10/14/2016	LAT	31.3715	
	1340	LONG	-80.9720	
4	10/14/2016	LAT	31.3183	wind_sp > 16 kts
	1825	LONG	-80.8177	
5	10/15/2016	LAT	32.3035	wind_sp >>16kts
T (B&C)	1845	LONG	-80.3057	
7	10/16/2016	LAT	31.7832	wind_sp >>16kts
	1545	LONG	-80.5820	
8	10/16/2016	LAT	31.7028	wind_sp >>16kts
	1810	LONG	-80.4275	
9	10/16/2016	LAT	31.7272	wind_sp > 16 kts
	2050	LONG	-80.3845	
10	10/17/2016	LAT	32.4335	blue water
	1410	LONG	-78.8830	
11	10/17/2016	LAT	32.6340	blue-green
	1805	LONG	-79.0792	
12	10/17/2016	LAT	32.7942	green
	2035	LONG	-79.2692	
13	10/18/2016	LAT	32.6842	turbid and oily
	1405	LONG	-79.6868	

Automated processing application to compute Remote Sensing Reflectance from Spectral Evolution



Automated processing application to compute Remote Sensing Reflectance from Spectral Evolution above water radiance measurements. Statistical procedures are used to remove outliers and data is resampled and binned to a standard grid Data from Nancy Foster Cruise is shown.

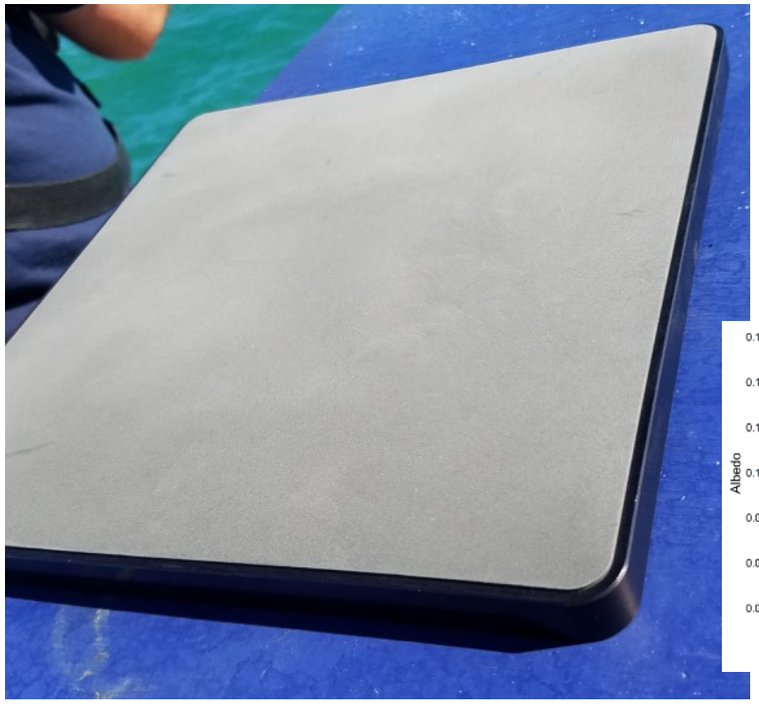




PLAQUE DIFFERENCES

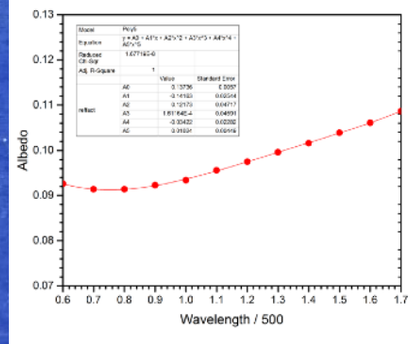


OSU_white



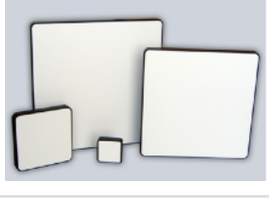
NRL_gray

courtesy
S. Ladner



STPECTRALON

https://www.labsphere.com/site/assets/files/1828/spectralon_targets.pdf



All Stations

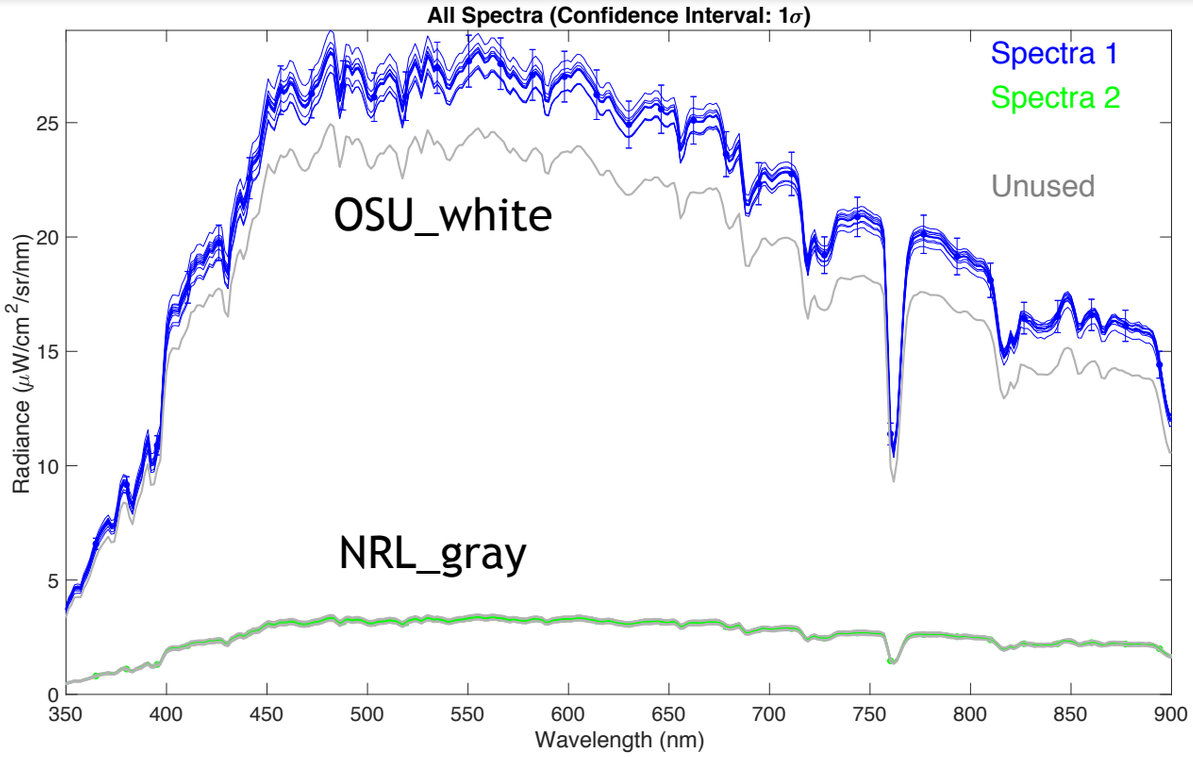
NIST_blue

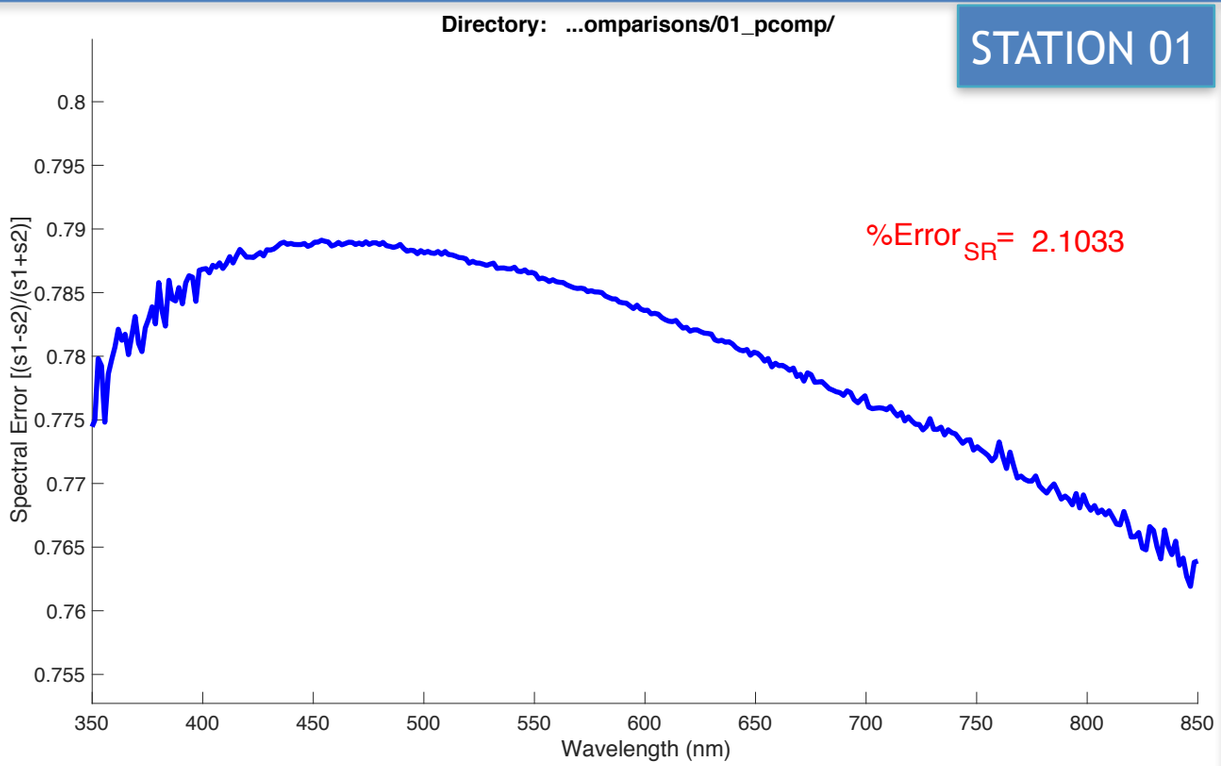
Schematic

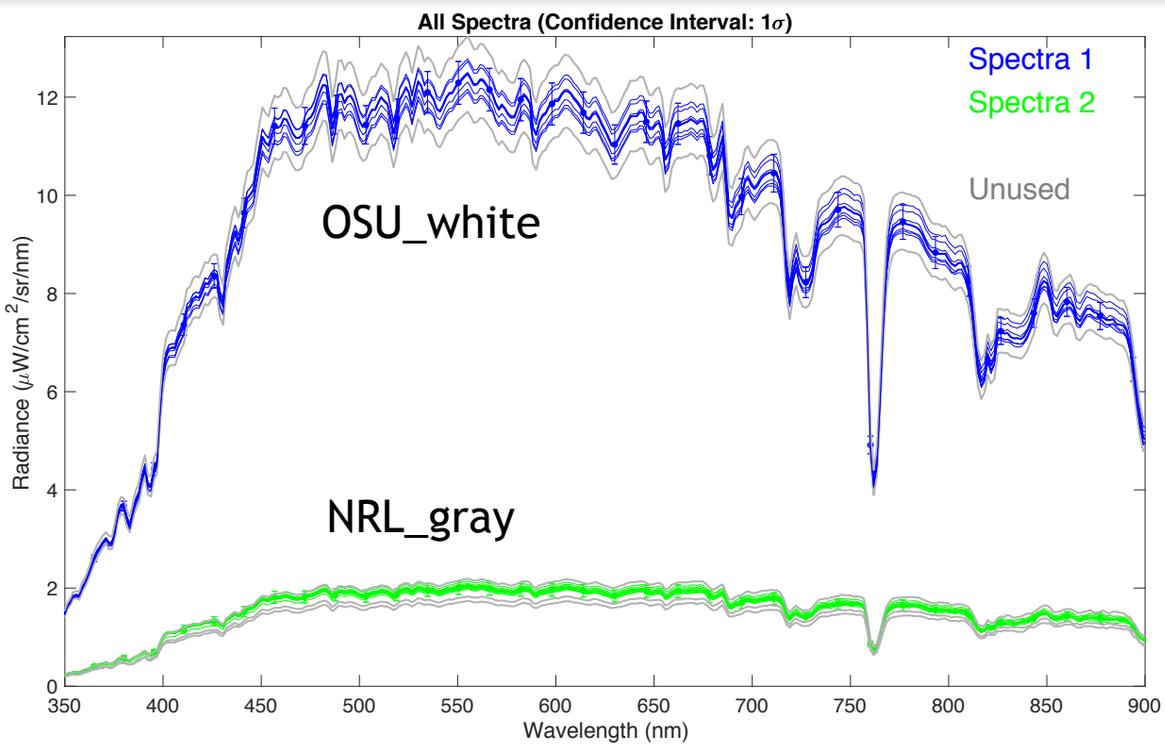
Stations 05 and 11 only

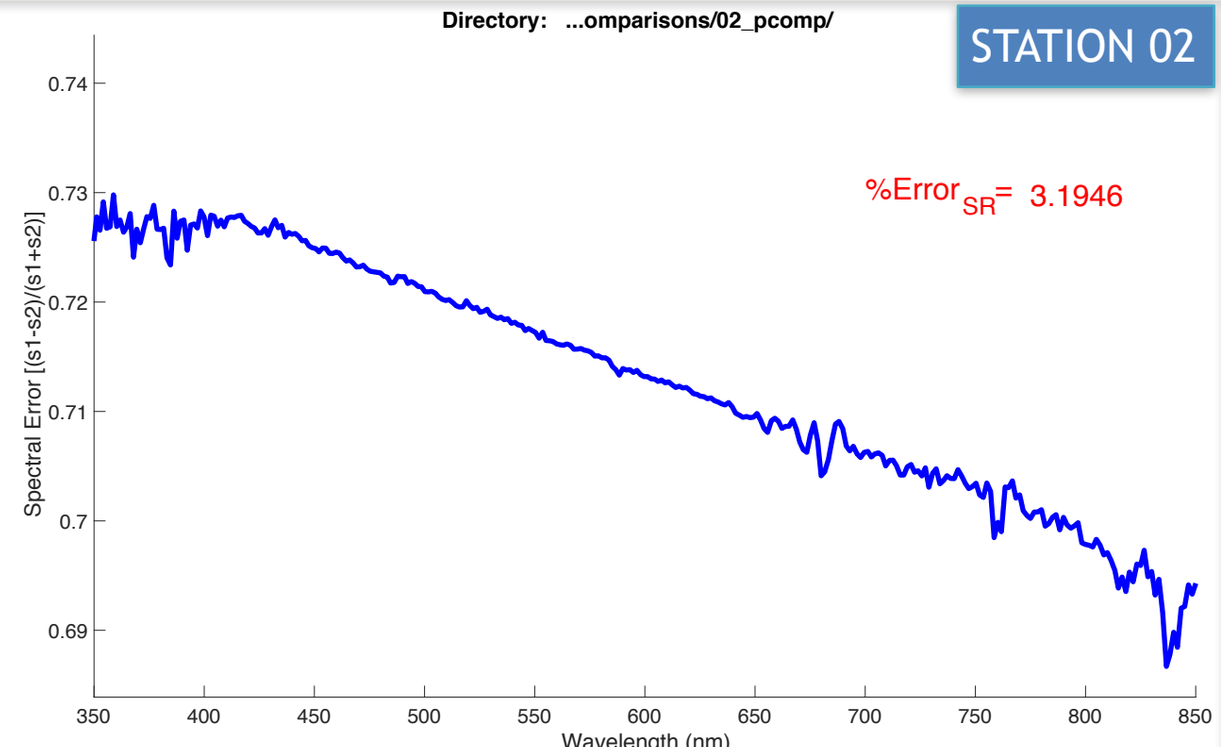
NRL_g and OSU_w PLAQUE DIFFERENCES 10/13/2016

— *Spectral Evolution CONSECUTIVE MEASUREMENTS, STATION 01 & 02*









SUMMARY AND OBSERVATIONS

- R_{RS} obtained for all stations from measured spectra S_{ref}, S_{w+s}, S_{sky}; R_{RS} = (S_{w+s} - S_{sky}*M)/(pi*S_{ref}/0.99), where M is Mobley correction
  - Qualitatively matches HyperPro results for most stations

- Quantified differences between reference plaques measured consecutively for OSU SEV instrument: OSU_{white}, NRL_{grey}, $NIST_{blue}$
  - Typical contribution to spectral error: 2~5%

- Experimental uncertainty needs better quantification
  - Challenges due to varying reflections from nearby surfaces (hull, bridge, etc.) on-board the Nancy Foster
    => Comprehensive error-budget needed (instruments, plaques, FOV, angular and temporal acquisition differences)
    => Define error component analysis & quantification methods

  - Experimental uncertainty due to sea-state (winds >>16kts for 40% of the stations)
    => Implementing new baseline reconstruction algorithms for OSU data processing of above water measurements

Working on new data products by ‘fusing’ data from VIIRS with Sentinel-2, GOES-R that builds on NOAA’s ‘Variational’ methods.

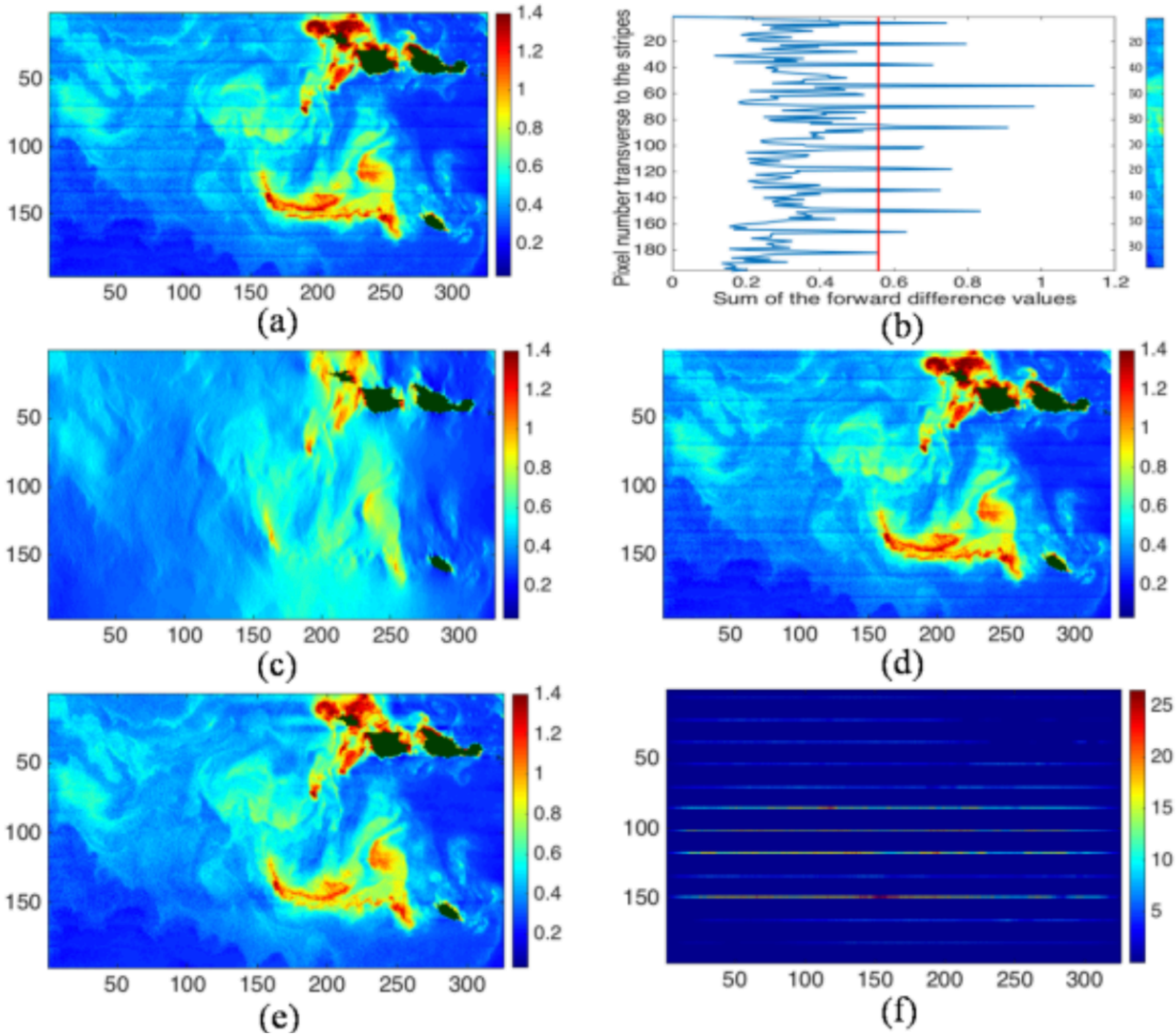


Figure 7. Panel **(a)** shows the cropped region shown in Fig. 6 and the graph **(b)** shows the S curve with the threshold and the image piece (columns 137 to 148) that we used compute the values of S curve. The panels **(c)**, **(d)** and **(e)** represent the destriped images of **(a)** with $\alpha = 1$ with unweighted regularization term and $\alpha = 10^{-5}$ and $\alpha = 10^{-2}$ with weighted regularization term, respectively. Panel **(e)** provides the best solution for the destriped image. Panel **(c)** is over regularized whereas panel **(d)** is not sufficiently regularized. Panel **(f)** represents the percentage error between panels **(a)** and **(e)**.

Regularization destriping of remote sensing imagery, Nonlinear Processes in Geophysics., 24, 367–378, 2017.

Current Work

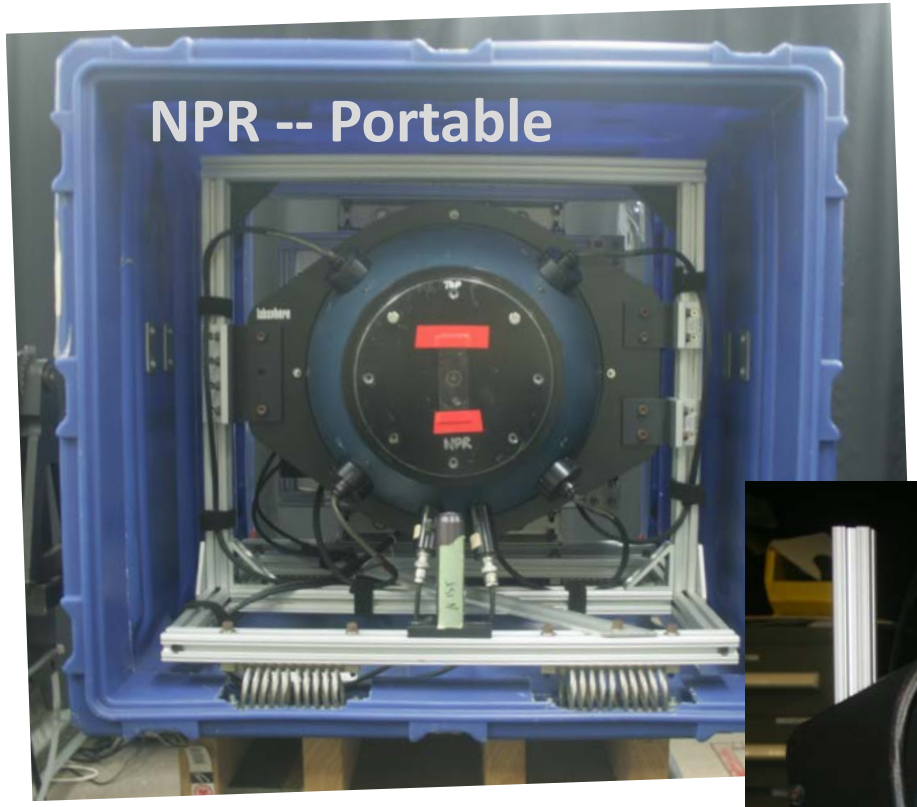
- Fall Eureka Cruise
- Side by Side Field Cal/Variance SeaPRISM paper
- Working on new products using data fusion with VIIRS and other sensors (Sentinel-2, Landsat-8, GOES-R, …)
- Working on protocols for both hand-held spectrometers as well as HyperPROs with NOAA.


04 April 2017

VIIRS Ocean Color Science Meeting

NPR, NII, and VXR Time Series

Carol Johnson







NPR and NII Integration Sphere Spectral Radiance Source Standards

VXR Portable Filter Radiometer, 6 channels at SeaWiFS type bands

Three Applications

- The Nxx spectral radiance $L(\lambda)$ and the VXR relative spectral responsivites (RSRs) are known: **Calibrate VXR with the Nxx spheres**
- The Nxx $L(\lambda)$ is unknown but the absolute spectral responsivities (ASRs) of the VXR bands are known: **Calibrate the Nxx spheres at the 6 VXR wavelengths**
- Both $L(\lambda)$ and the ASRs are known: **Validate the Nxx and VXR values**, as well as the veracity of the VXR to transfer between source and detector – based facilities (e.g. FASCAL and SIRCUS at NIST)

Interpolations are Required

$$S_b = \int L(\lambda) F_b\, r_b(\lambda)\, d\lambda$$

$$\lambda_{b,m} = \frac{\int \lambda\, L(\lambda) F_b\, r_b(\lambda)\, d\lambda}{\int L(\lambda) F_b\, r_b(\lambda)\, d\lambda} = \frac{\int \lambda\, L(\lambda)\, r_b(\lambda)\, d\lambda}{\int L(\lambda)\, r_b(\lambda)\, d\lambda}$$

$$\Delta\lambda_{b,m} = \frac{\int L(\lambda) F_b\, r_b(\lambda)\, d\lambda}{L(\lambda_{b,m}) F_b\, r_b(\lambda_{b,m})} = \frac{\int L(\lambda)\, r_b(\lambda)\, d\lambda}{L(\lambda_{b,m})\, r_b(\lambda_{b,m})}$$

S = Signal, *b* = filter band, *F*r* = ASR, *r* = RSR

The moment wavelengths and the bandpasses are the same for ASR or RSR values, but vary with the spectral distribution of the source – by how much depends on the spectral out of band in the filters

$$F_b\, r_b(\lambda_{b,m}) = \frac{S_b}{L(\lambda_{b,m})\, \Delta\lambda_{b,m}}$$

Calibrate the VXR

$$L(\lambda_{b,m}) = \frac{S_b}{F_b\, r_b(\lambda_{b,m})\, \Delta\lambda_{b,m}}$$

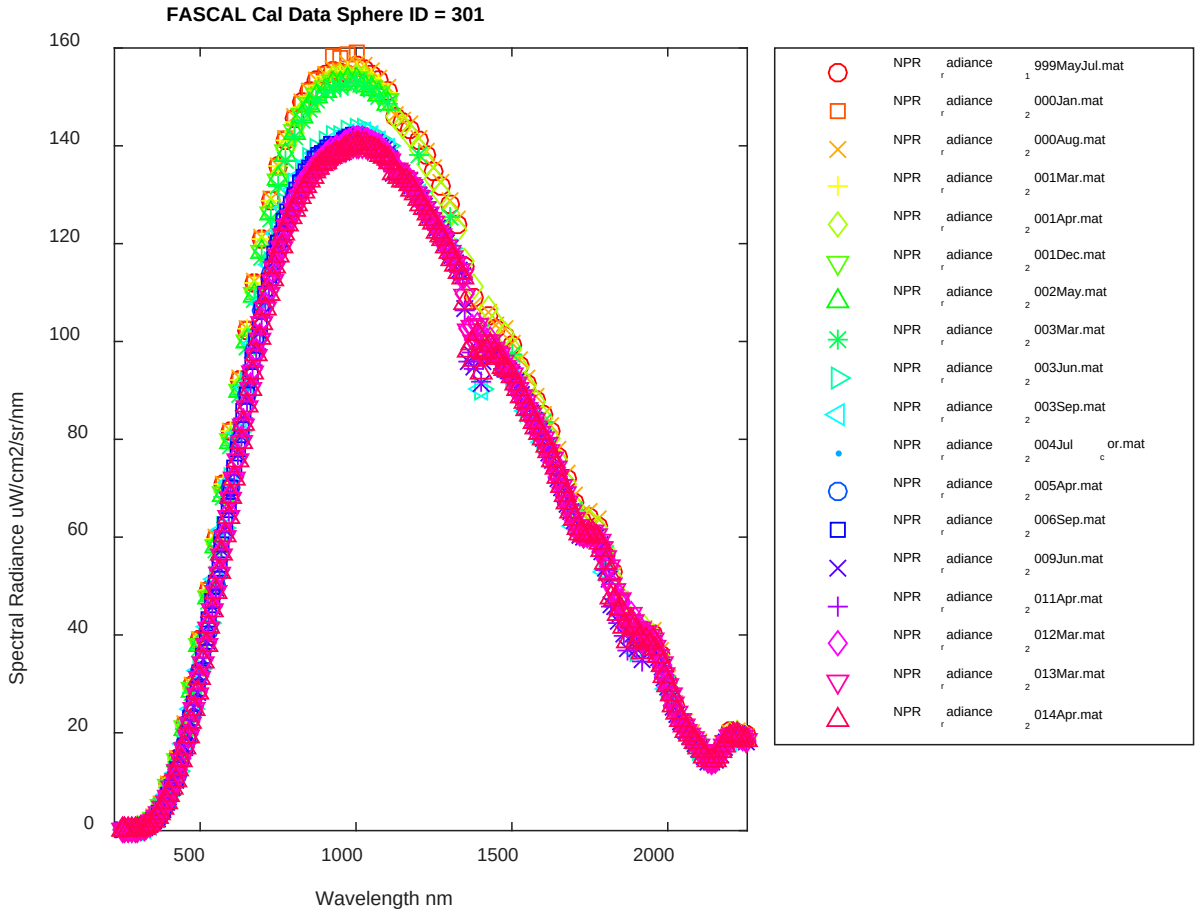
Calibrate the Nxx

$$\text{Does } S_b = L(\lambda_{b,m})\, F_b\, r_b(\lambda_{b,m})\, \Delta\lambda_{b,m} \text{ ?}$$

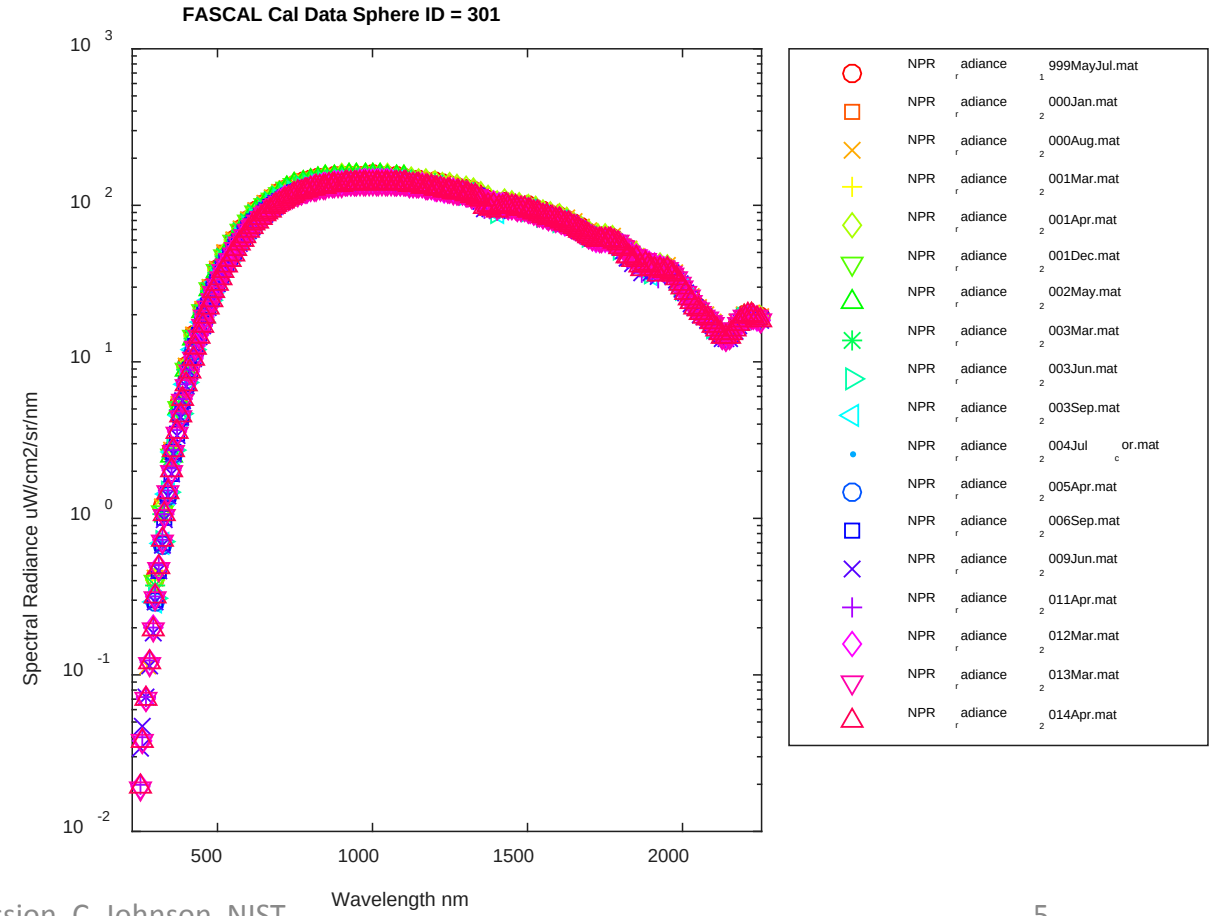
$$\text{Or, does } S_b = \int L(\lambda) F_b\, r_b(\lambda)\, d\lambda \text{ ?}$$

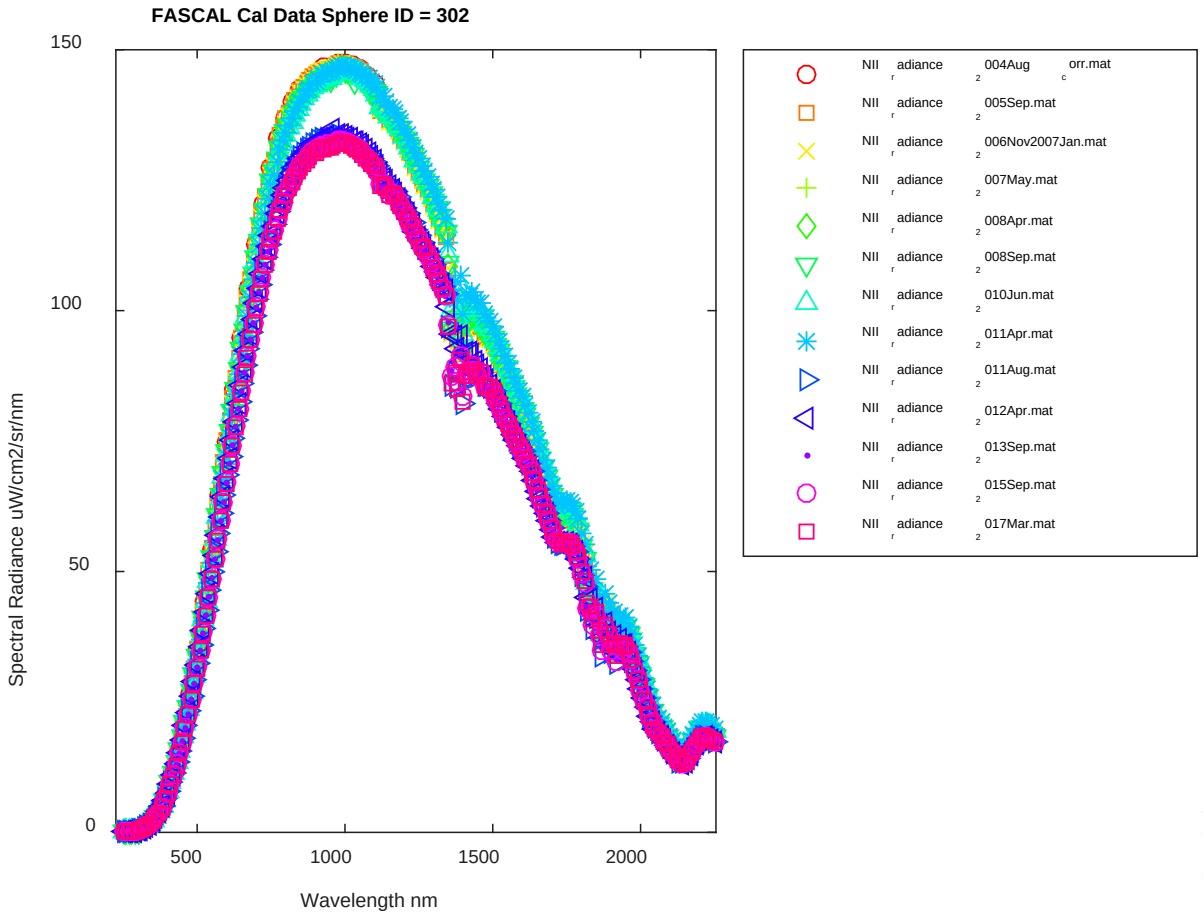
Validate FASCAL, SIRCUS, & VXR efficacy

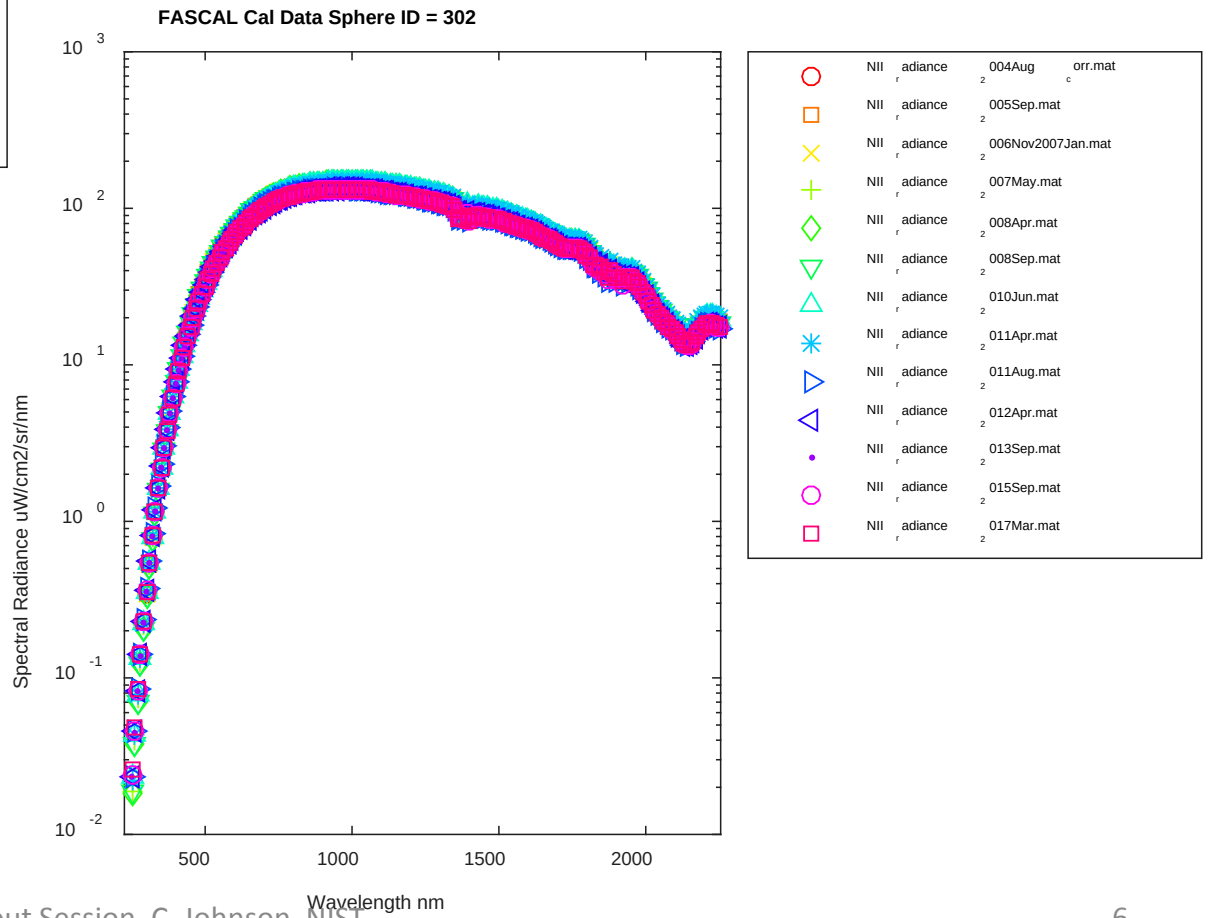
Parr and Johnson, *J. Res. NIST*, **116**, 751 – 760 (2011).



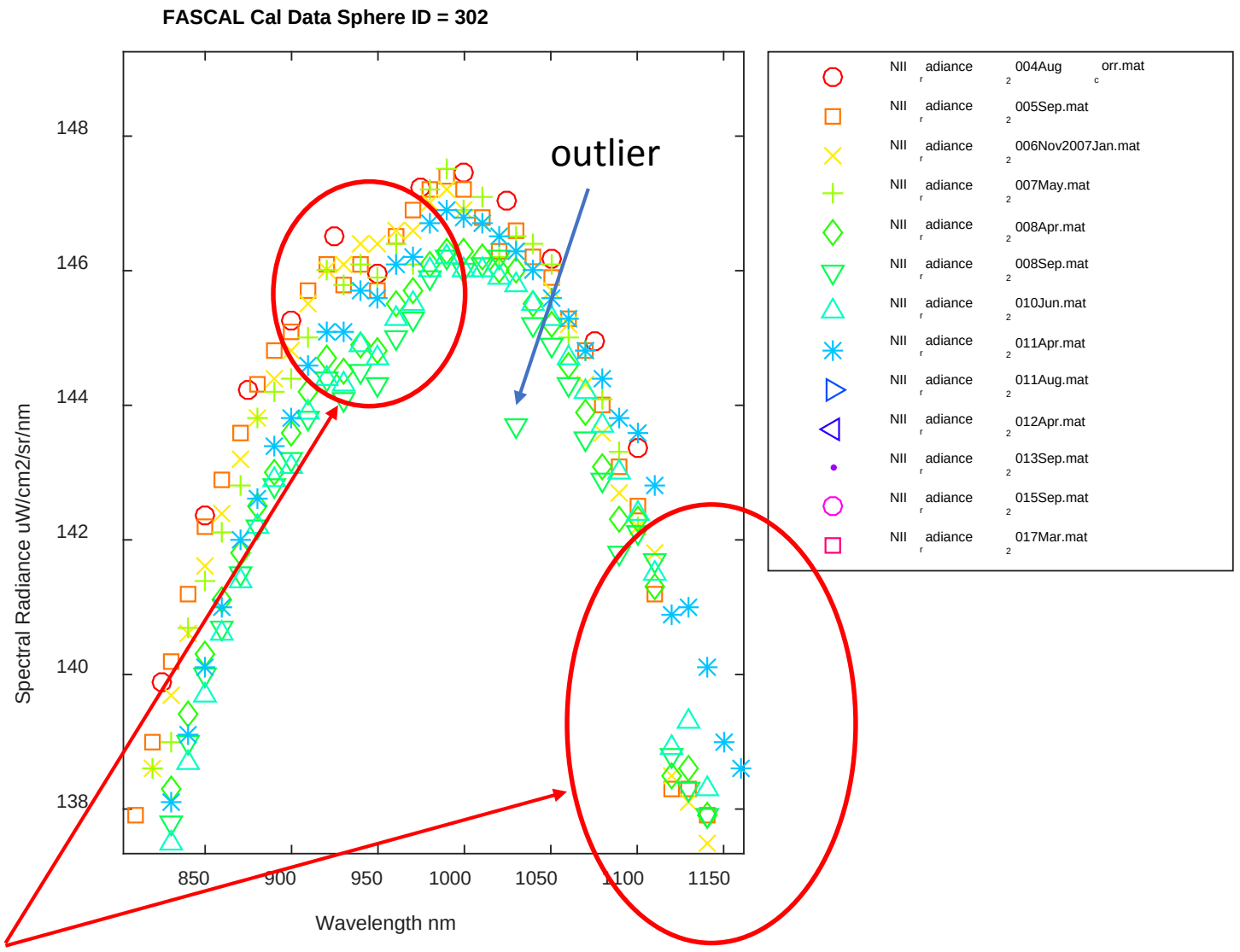
NPR FASCAL history, four lamp sets, multiple calibrations on each lamp set.
Data not uniform in spectral coverage or density of values. 18 Years of use.







NII FASCAL history, two lamp sets, multiple calibrations on each lamp set.
Data not uniform in spectral coverage or density of values. 13 Years of use.



atmospheric absorption

First Approach: Analytical function (physical basis, consistent interpretation of data, identification of outliers, estimates of uncertainty at interpolated points).

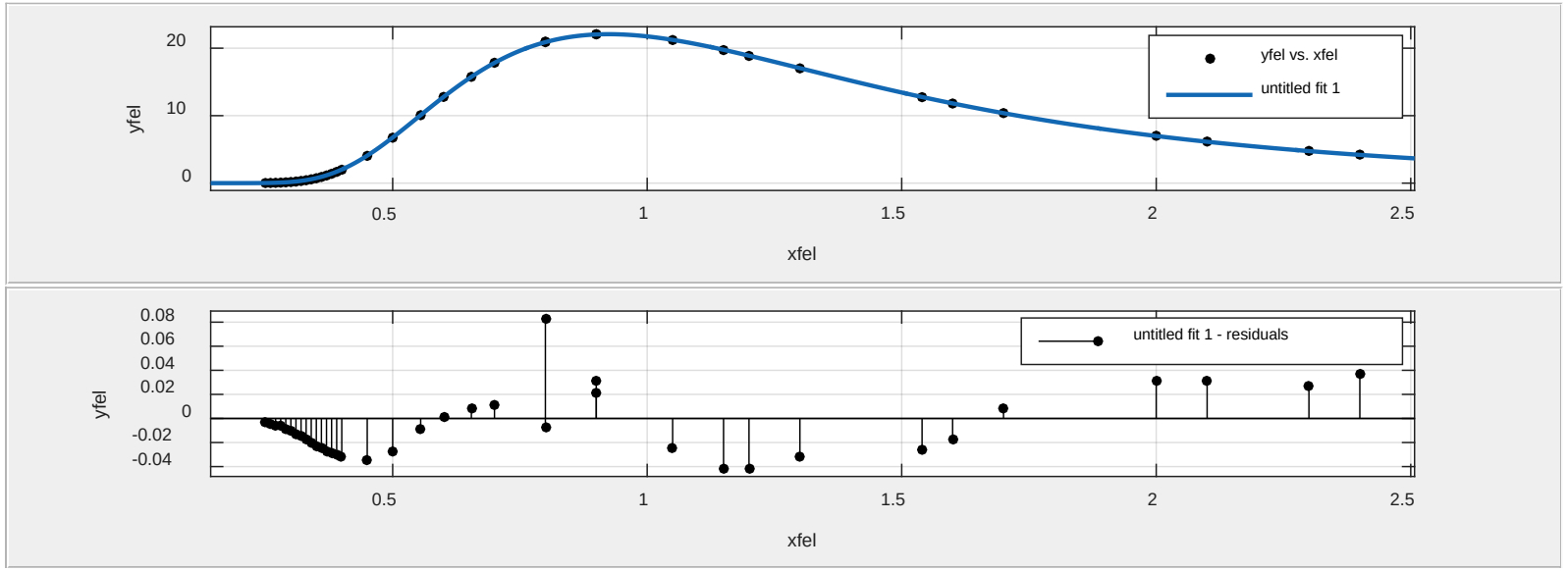
Regions of atmospheric features were excluded: 760 nm, 915 to 985 nm, 1100 to 1150 nm, 1300 to 1500 nm, & 1730 to 1980 nm (use of integrating sphere increases the path length)

The 1973 NBS Spectral Irradiance method was explored (region subdivided spectrally)

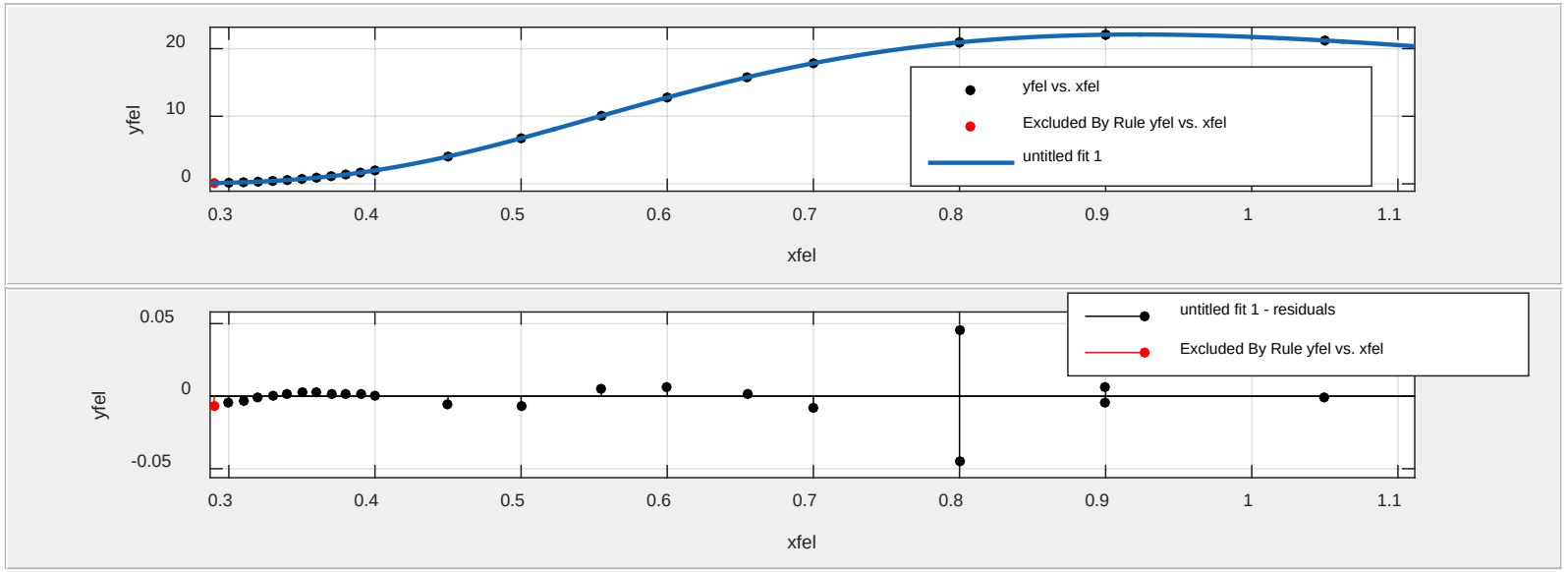
$$\ln(\lambda^5 L(\lambda)) = a + \frac{b}{\lambda}$$

$$L(\lambda) = \left[\sum_{i=0}^{n} c_i \lambda^i\right] \exp(b/\lambda)$$

FEL Irradiance standard (wavelength is in micrometers)



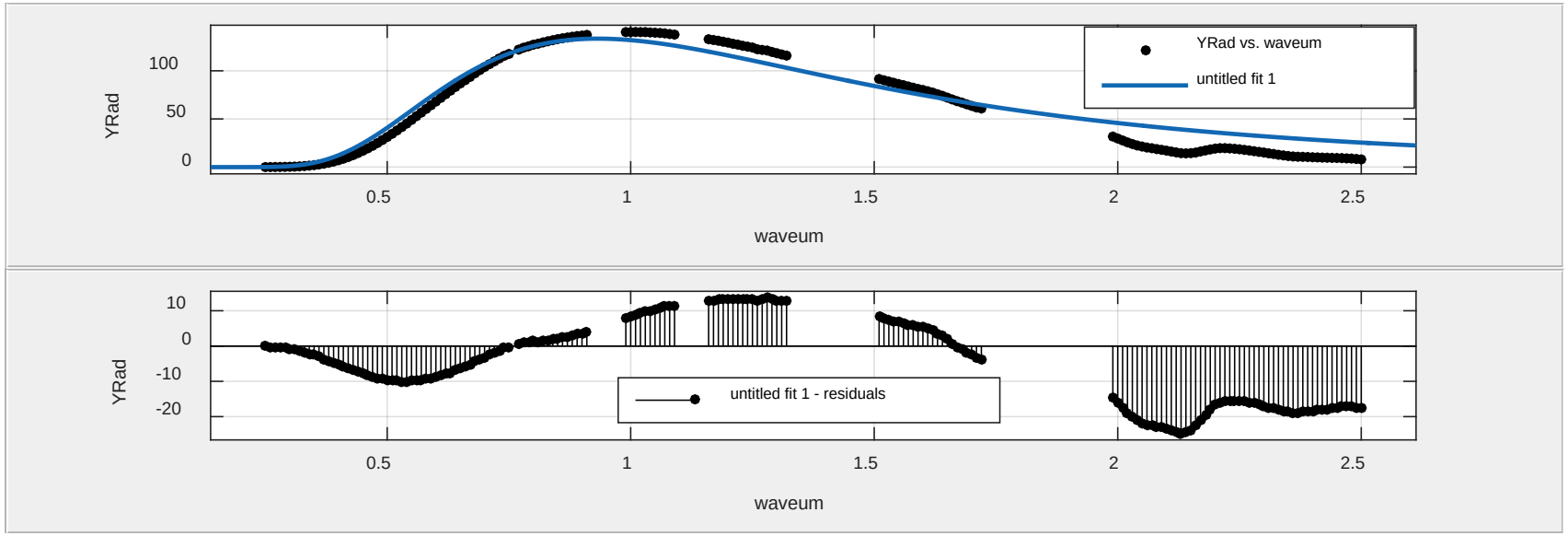
N = 1, full range, unweighted
SSE = 0.026, ADRS = 1



N = 4, 300 nm to 1100 nm, unweighted
SSE = 0.004, ADRS = 1

Note: I'm fitting in one step – did not linearize the blackbody term

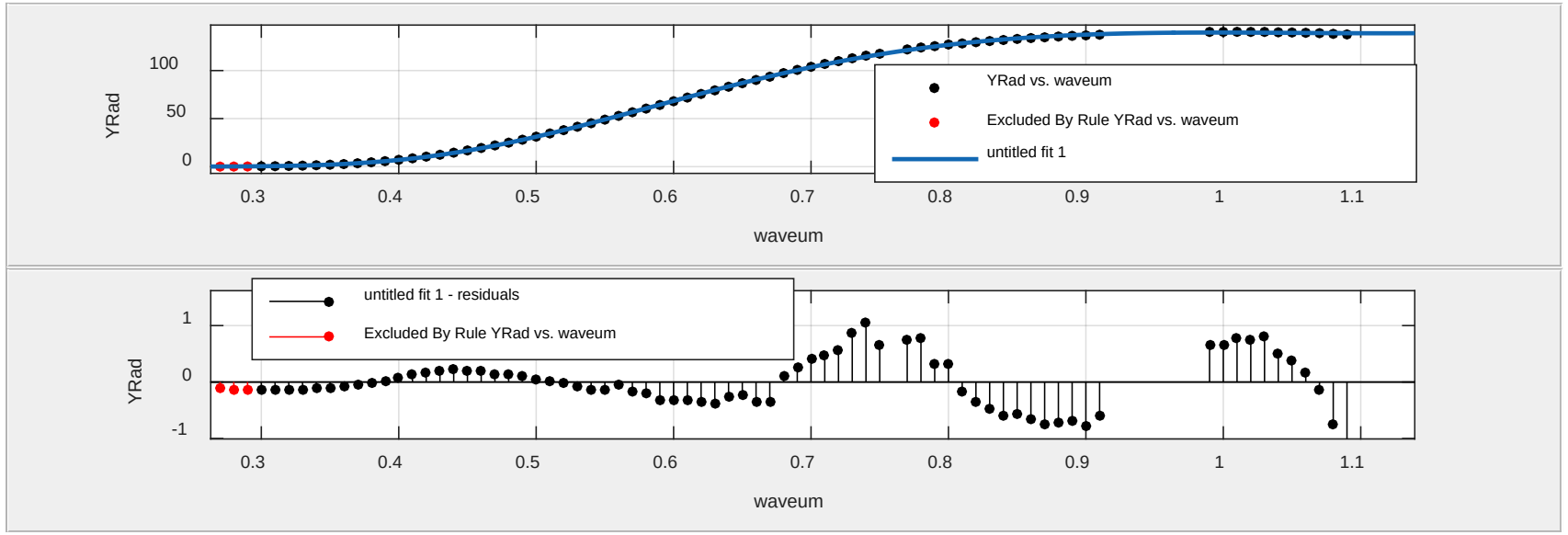
NPR April 2014 FASCAL data (wavelength is in micrometers)

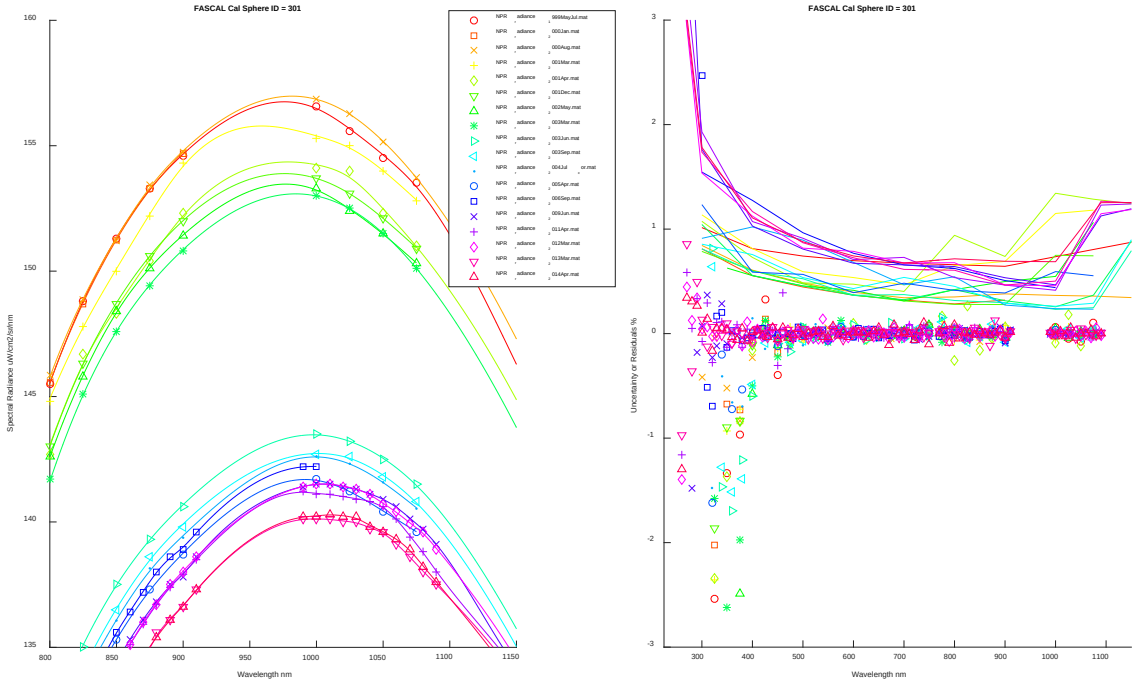


N = 0, full range, unweighted
SSE = 2.6E4, ADRS = 0.940

N = 4, 300 nm to 1100 nm, unweighted
SSE = 15.2, ADRS = 0.9999

Note: Residuals fall outside the FASCAL uncertainties; fit is sensitive to starting parameters; residuals have structure

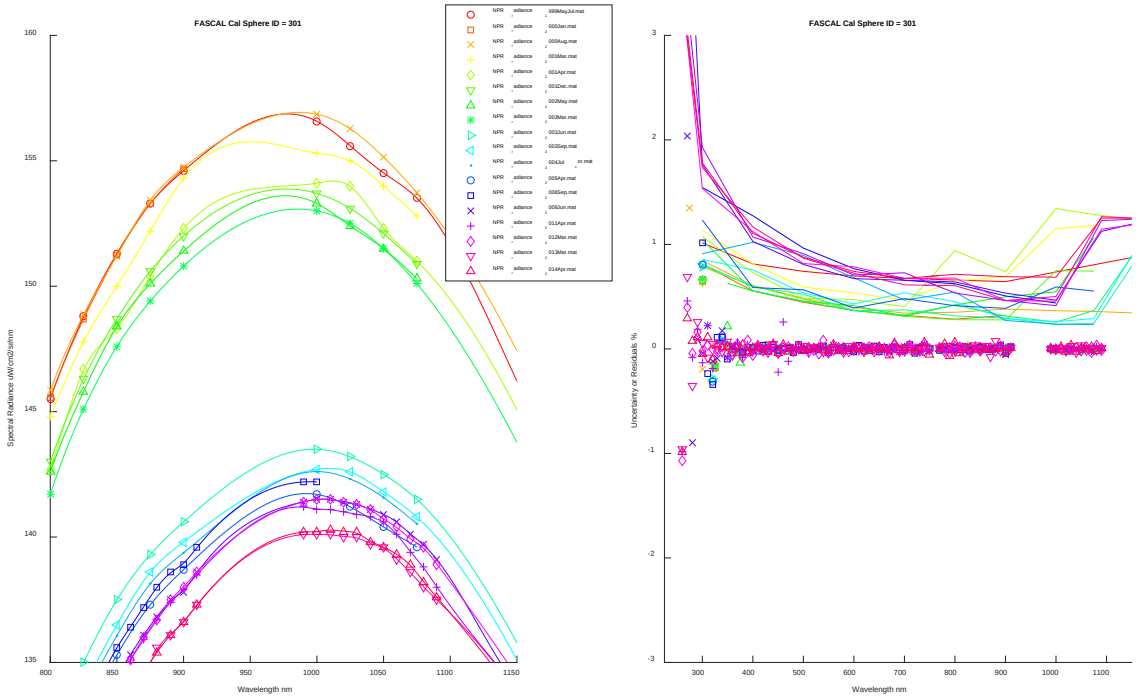


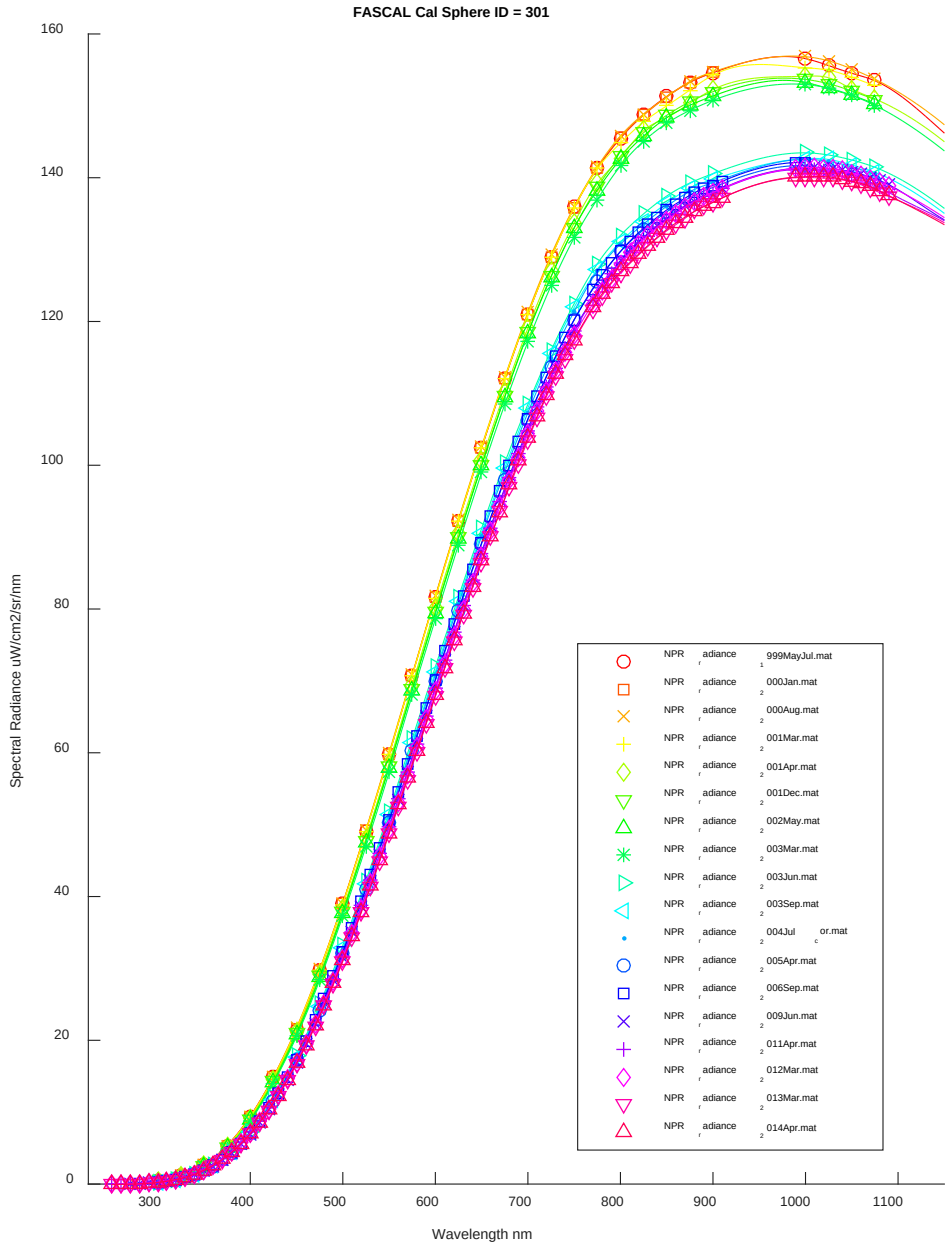


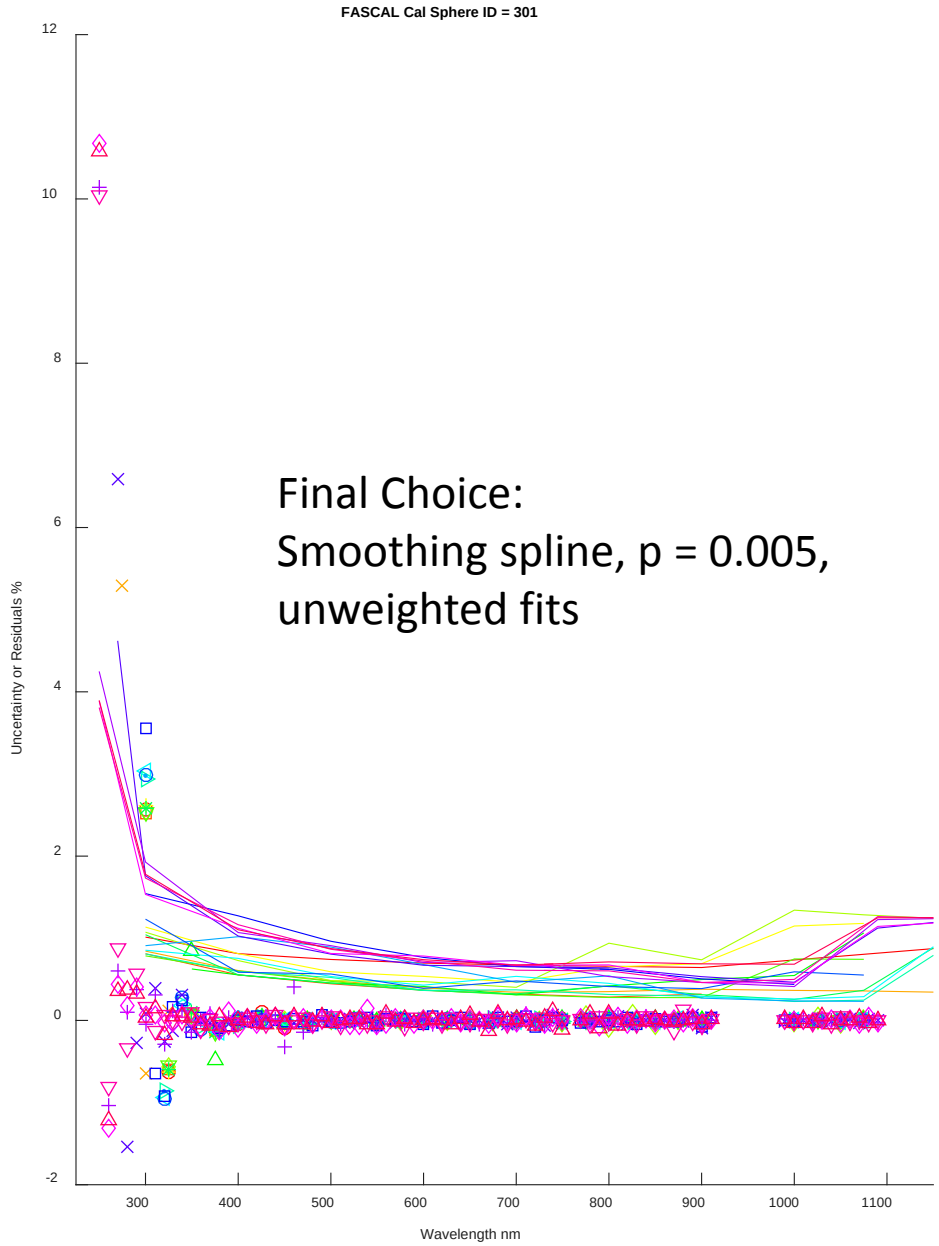
Smoothing spline, strong smoothing (p = 0.007)

Second approach: Interpolate with smoothing splines (new grid is every 0.1 nm)

Smoothing spline, weak smoothing (p = 0.02)



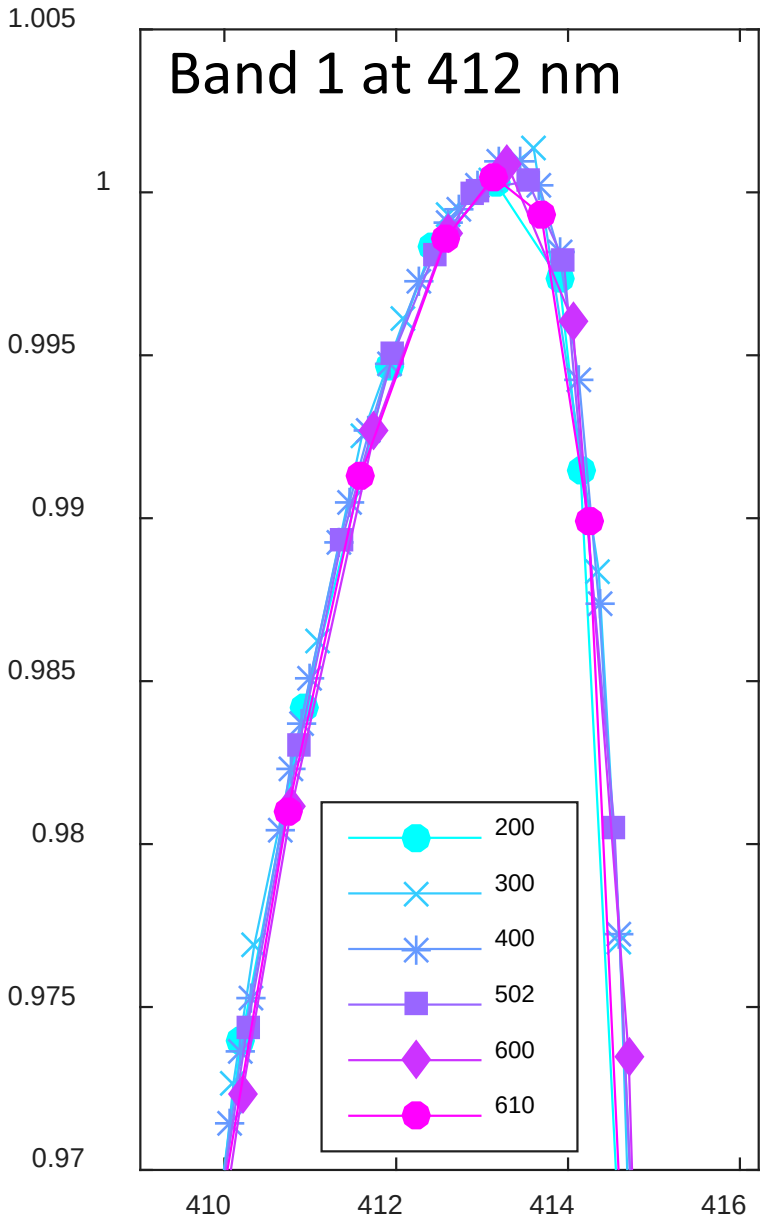


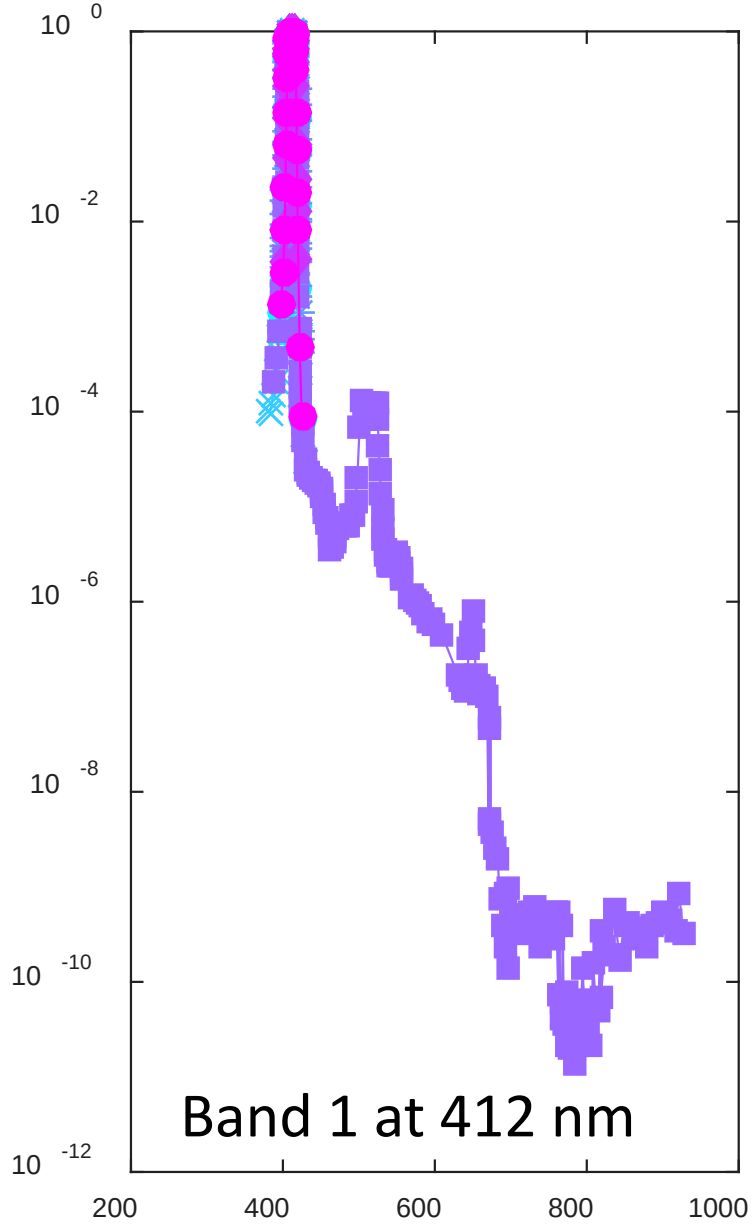


Final Choice:
Smoothing spline, p = 0.005,
unweighted fits

VXR RSRs

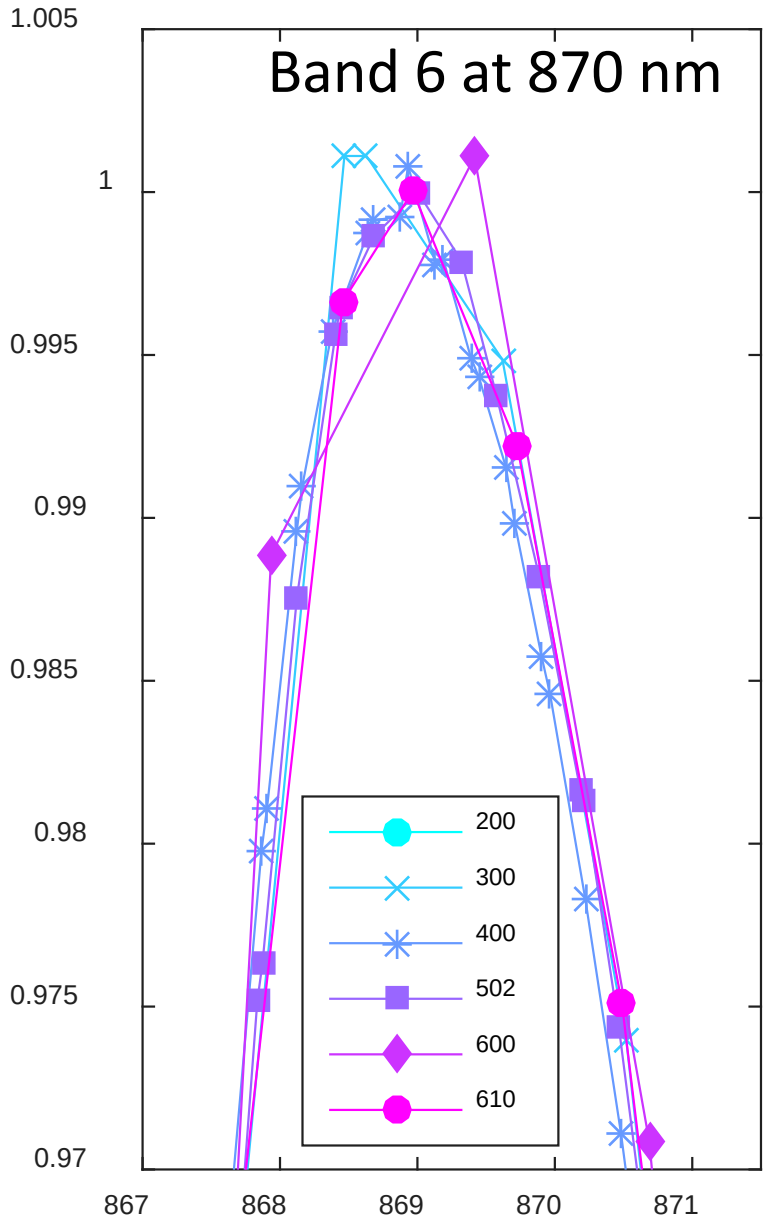
Composite of 6 SIRCUS ASR calibrations – 1999 to 2011

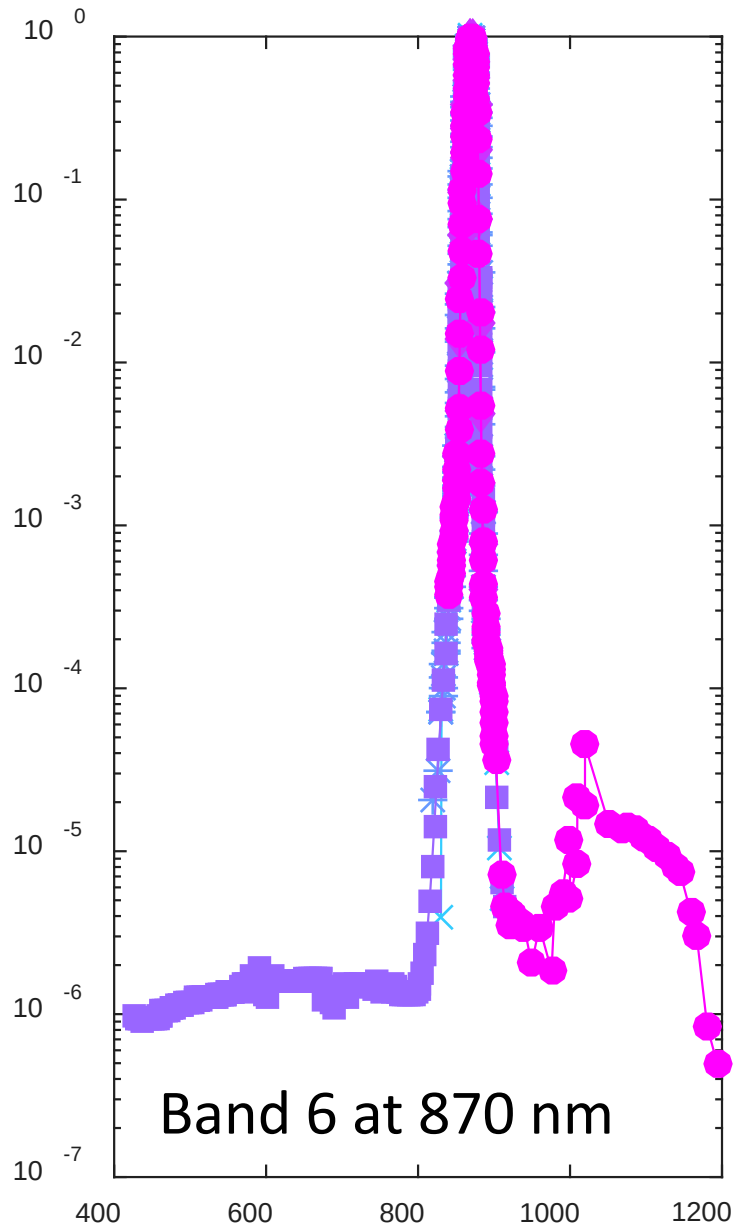


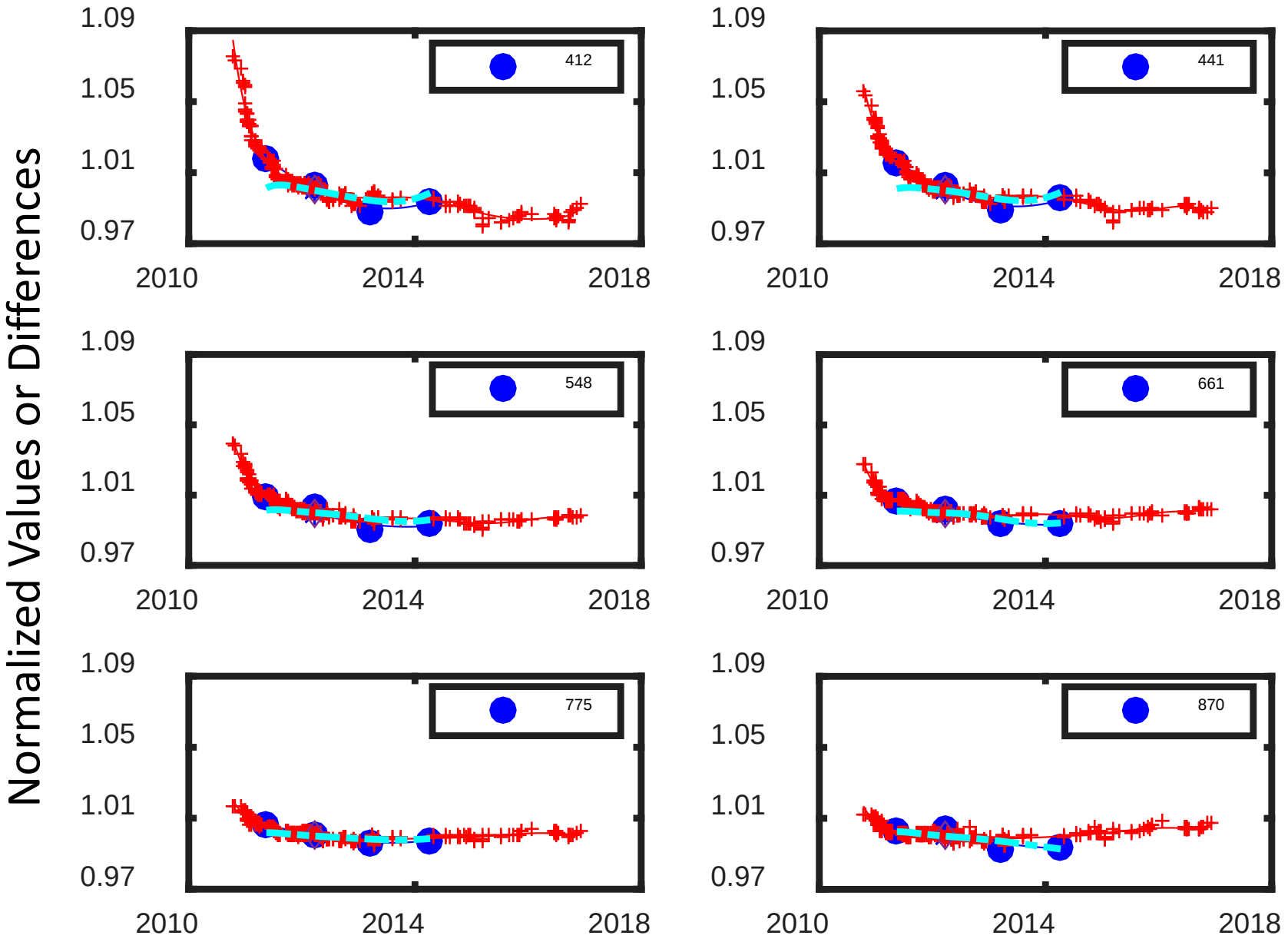


VXR RSRs

Composite of 6 SIRCUS ASR calibrations – 1999 to 2011







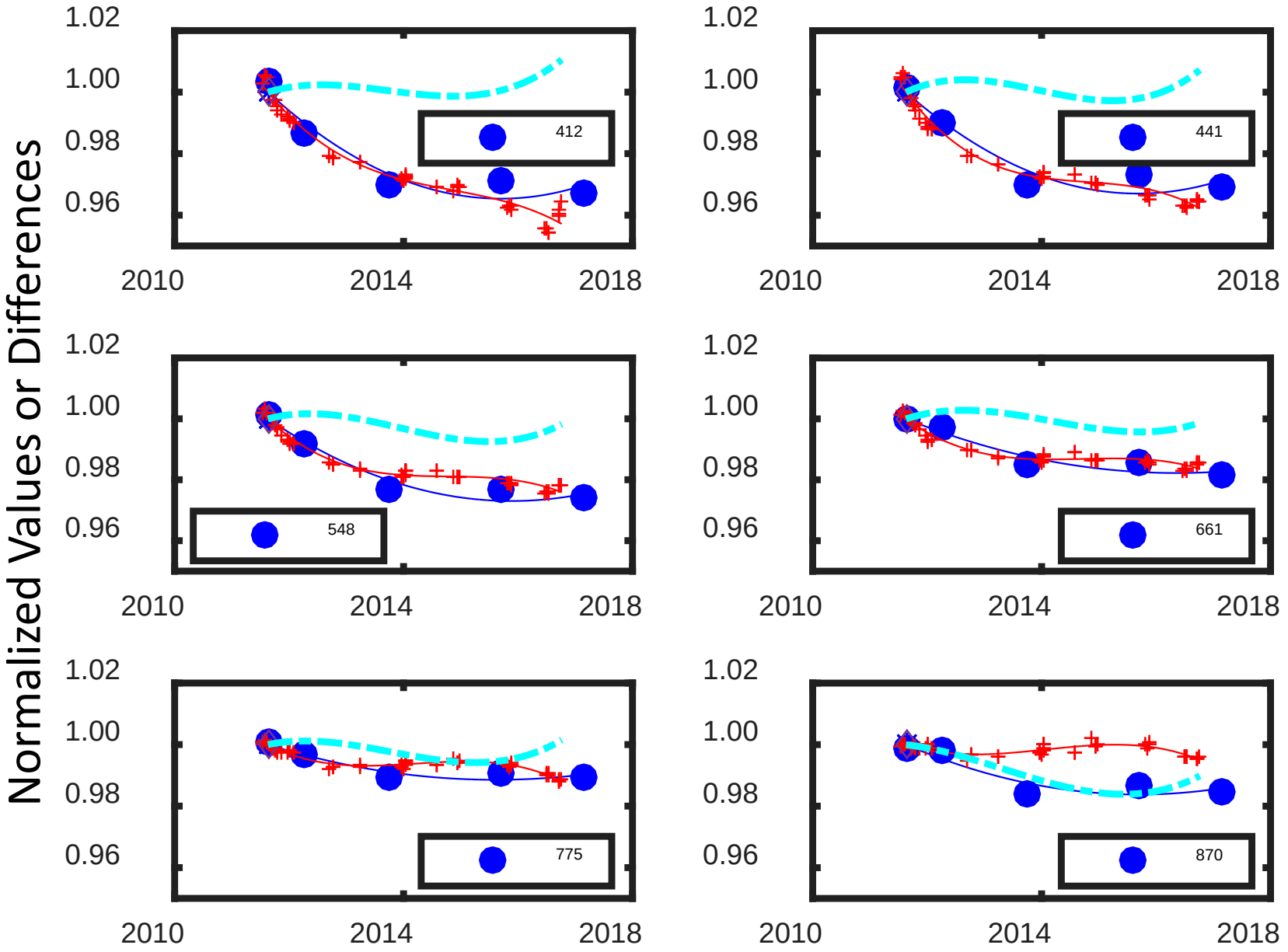
NPR Sphere Lamp Set 4

Blue: Band average FASCAL w VXR RSRs;
Red: VXR net signals; Lines = poly fits;

Cyan line = difference

$L(\lambda_{b,m},t)$ and $S_b(t)$ were normalized to the FASCAL time with the minimum difference to a VXR signal file

FASCAL: N = 2
VXR: N = 8



NII Sphere Lamp Set 2

Blue: Band average FASCAL w VXR RSRs;
Red: VXR net signals;
Lines = poly fits;

Cyan line = difference

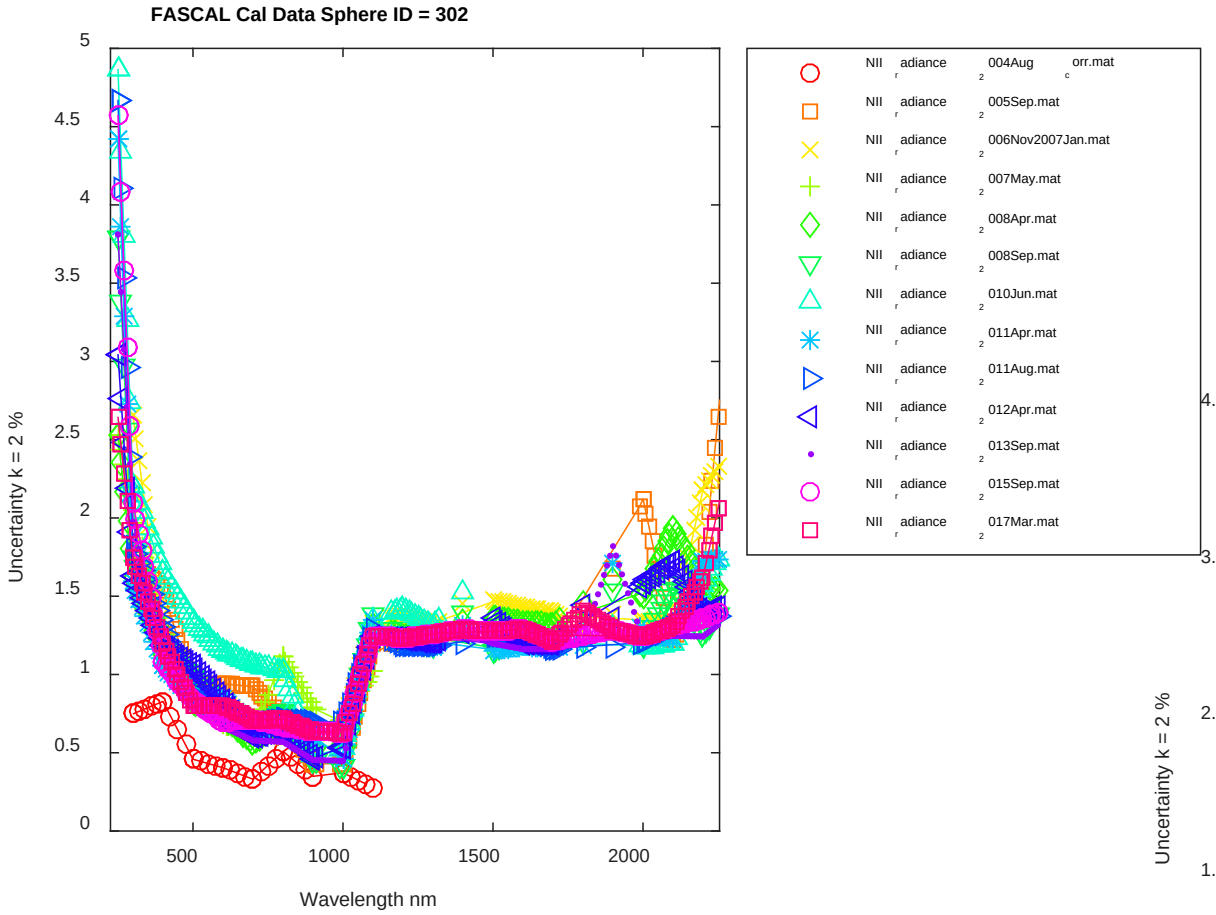
$L(\lambda_{b,m},t)$ and $S_b(t)$ were normalized to the FASCAL time with the minimum difference to a VXR signal file

FASCAL: N = 2
VXR: N = 3

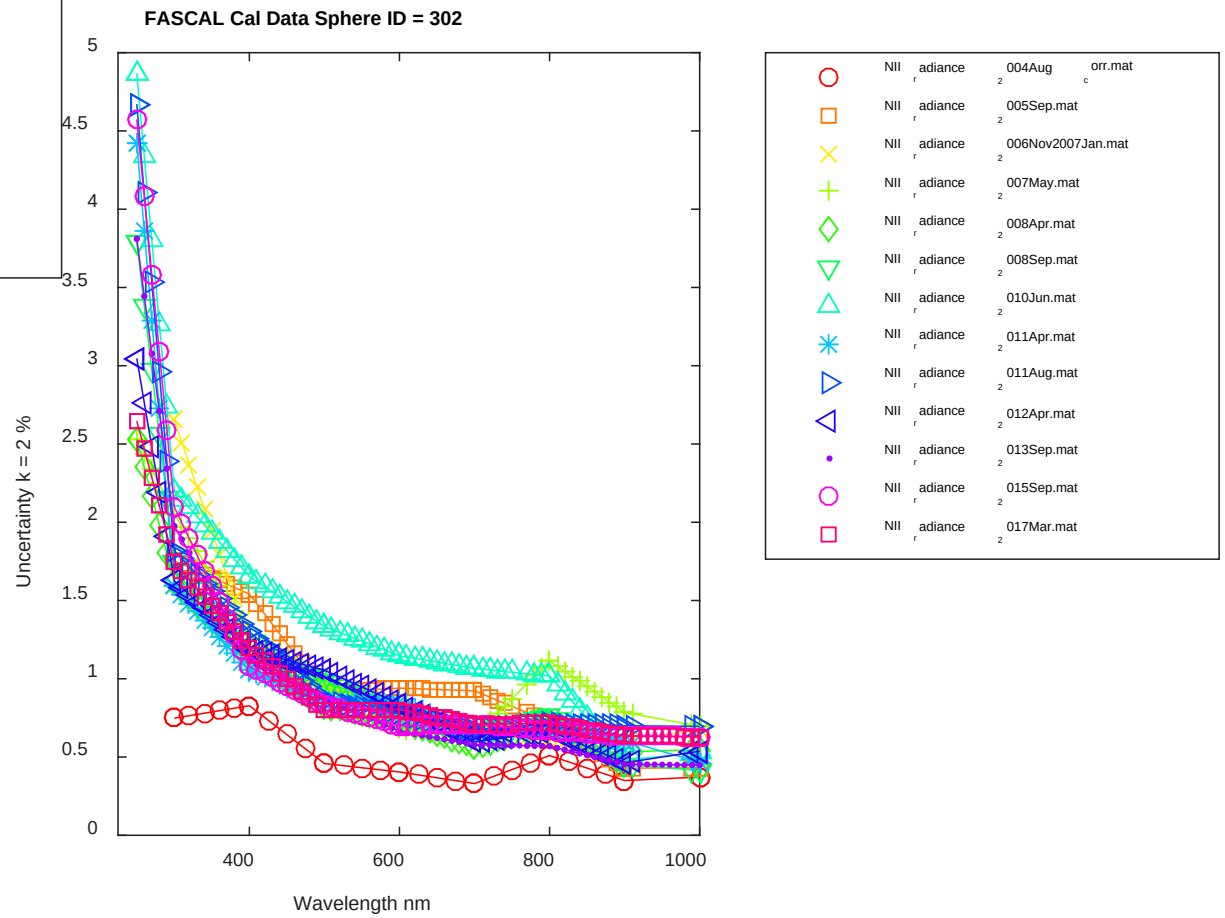
Observations & To Do

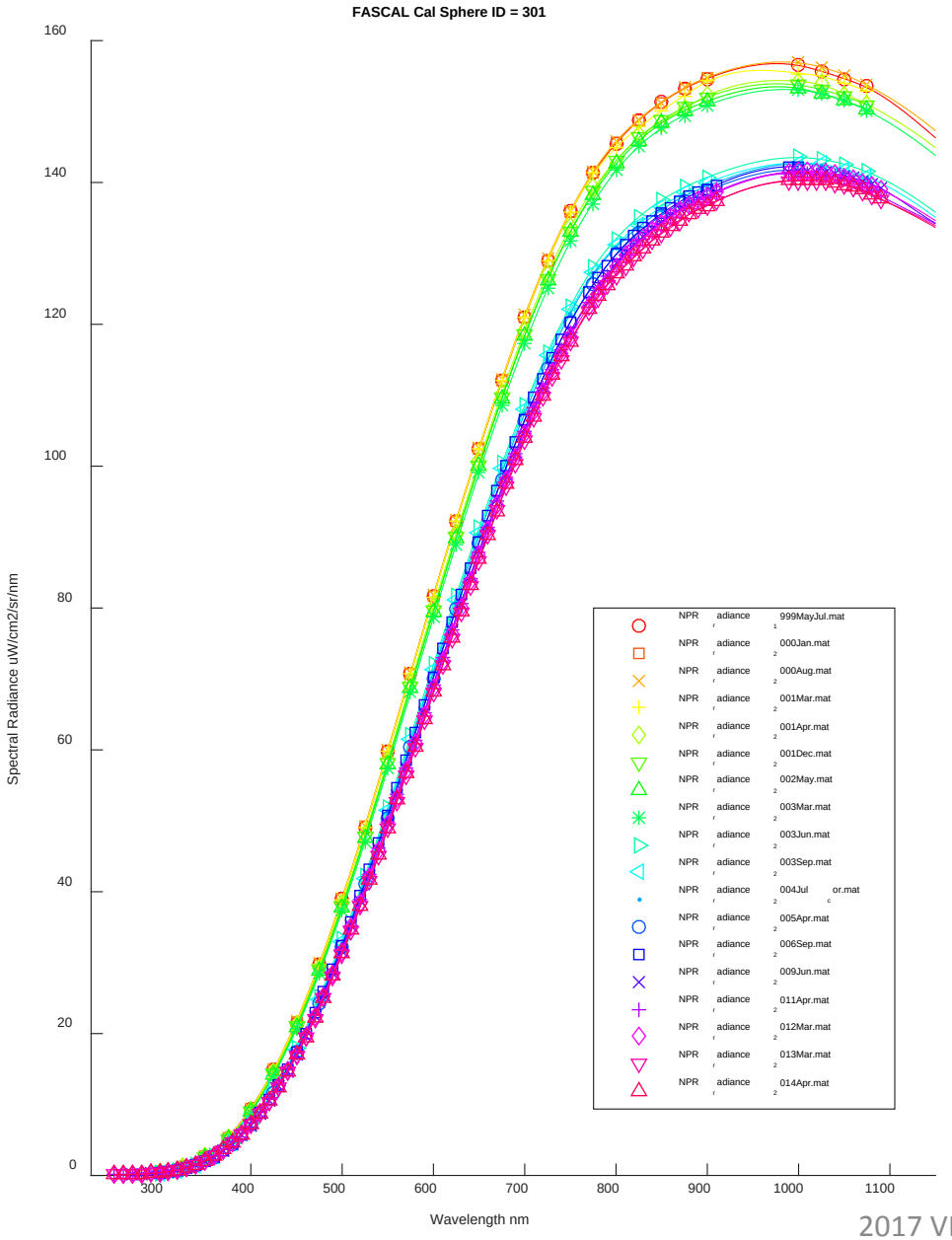
- Lamps operated de-rated last beyond the rated lifetime
- Repeated calibrations on one lamp set necessary
- Change in blue for NPR LS4 attributed to poorly seasoned lamps
- VXR and FASCAL agree to within 1%, indicates VXR stable over this time frame if we assume FASCAL is reproducible
- Four other lamp sets, with data back to 1999, remain
- Can use these results to assign ASRs and compare to the SIRCUS results for the VXR (six different calibrations, 1999 to 2011).
- Integrating spheres more difficult to model than FELs or FELs/plaque

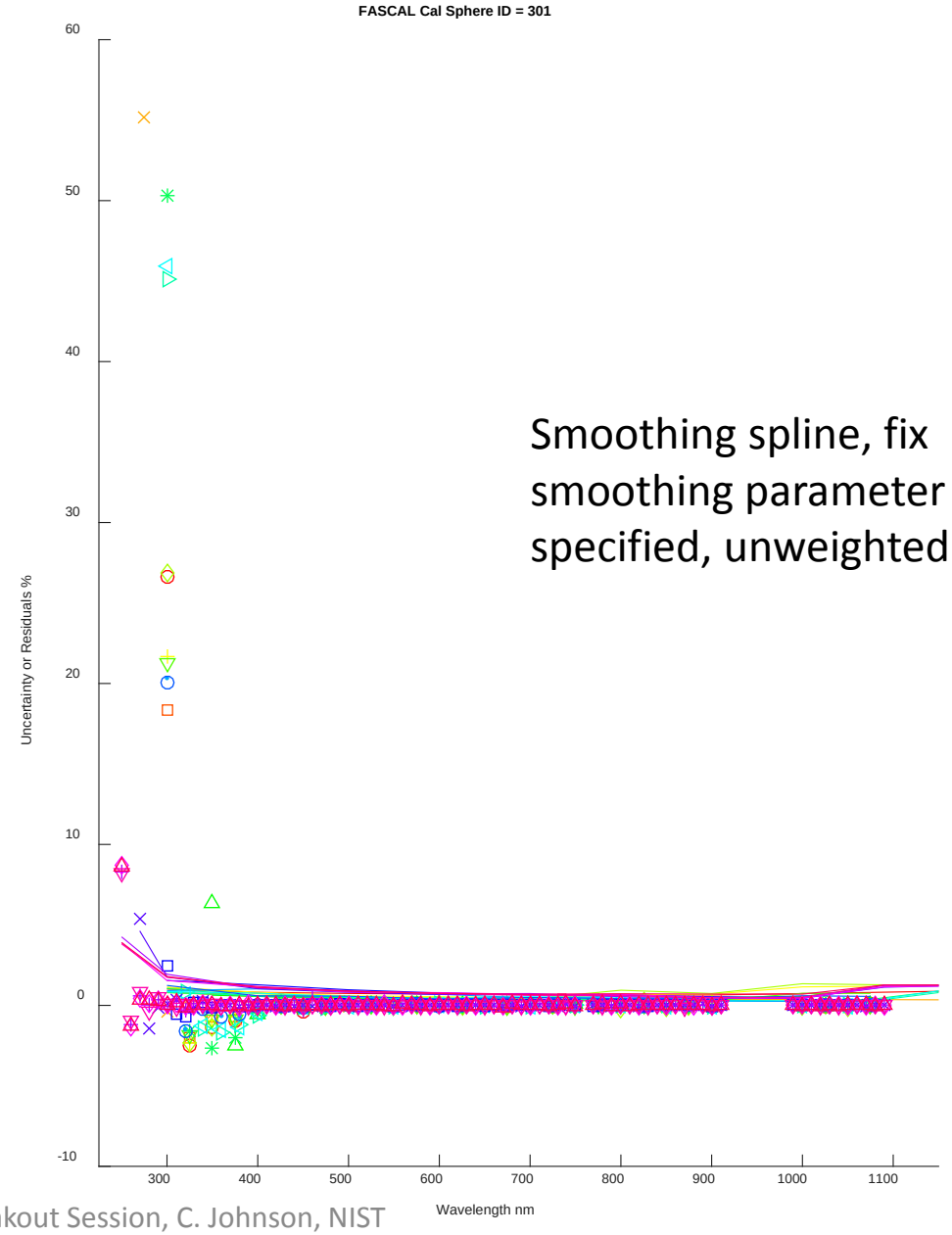
Backup



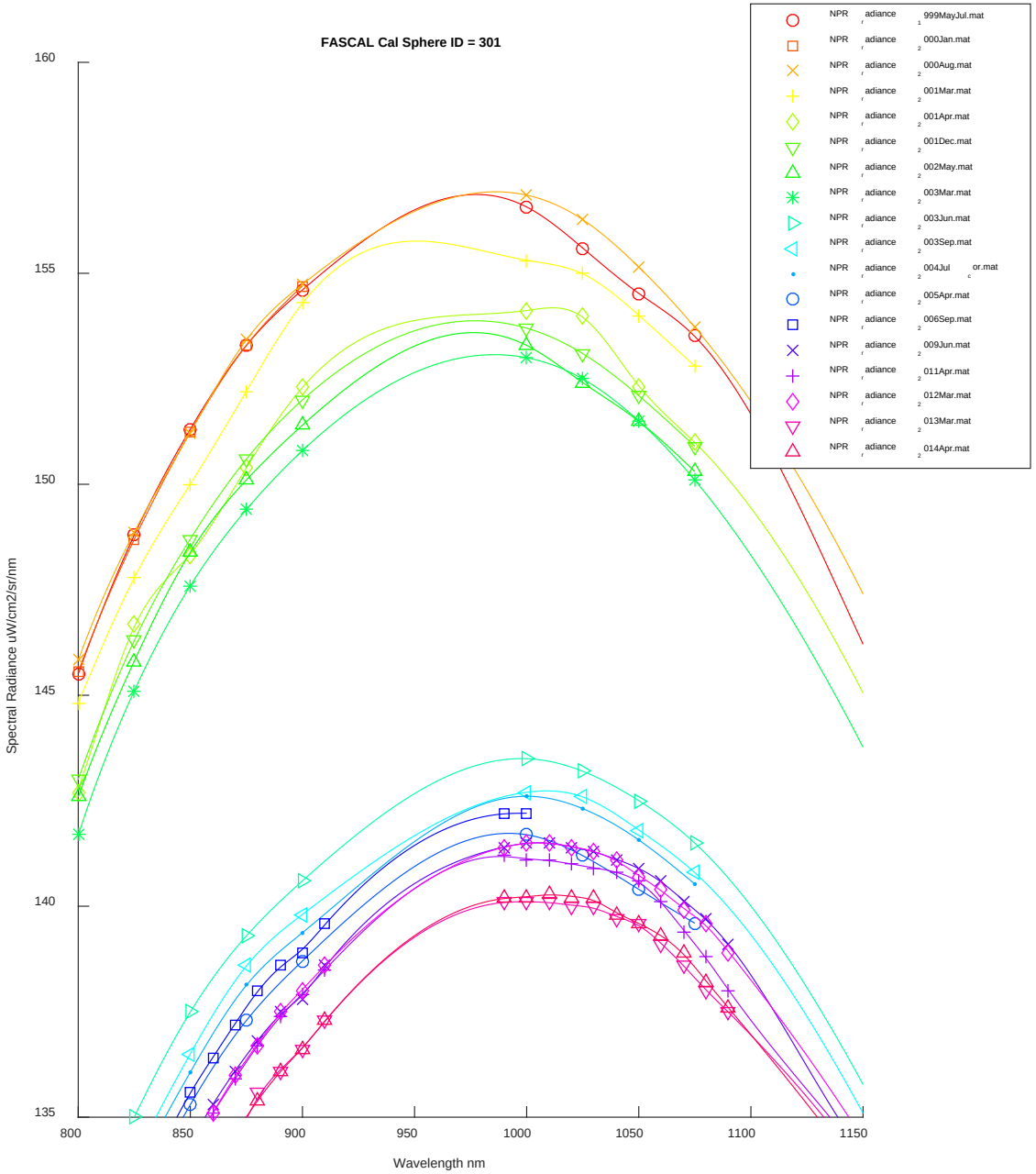
Expanded uncertainties over the full range

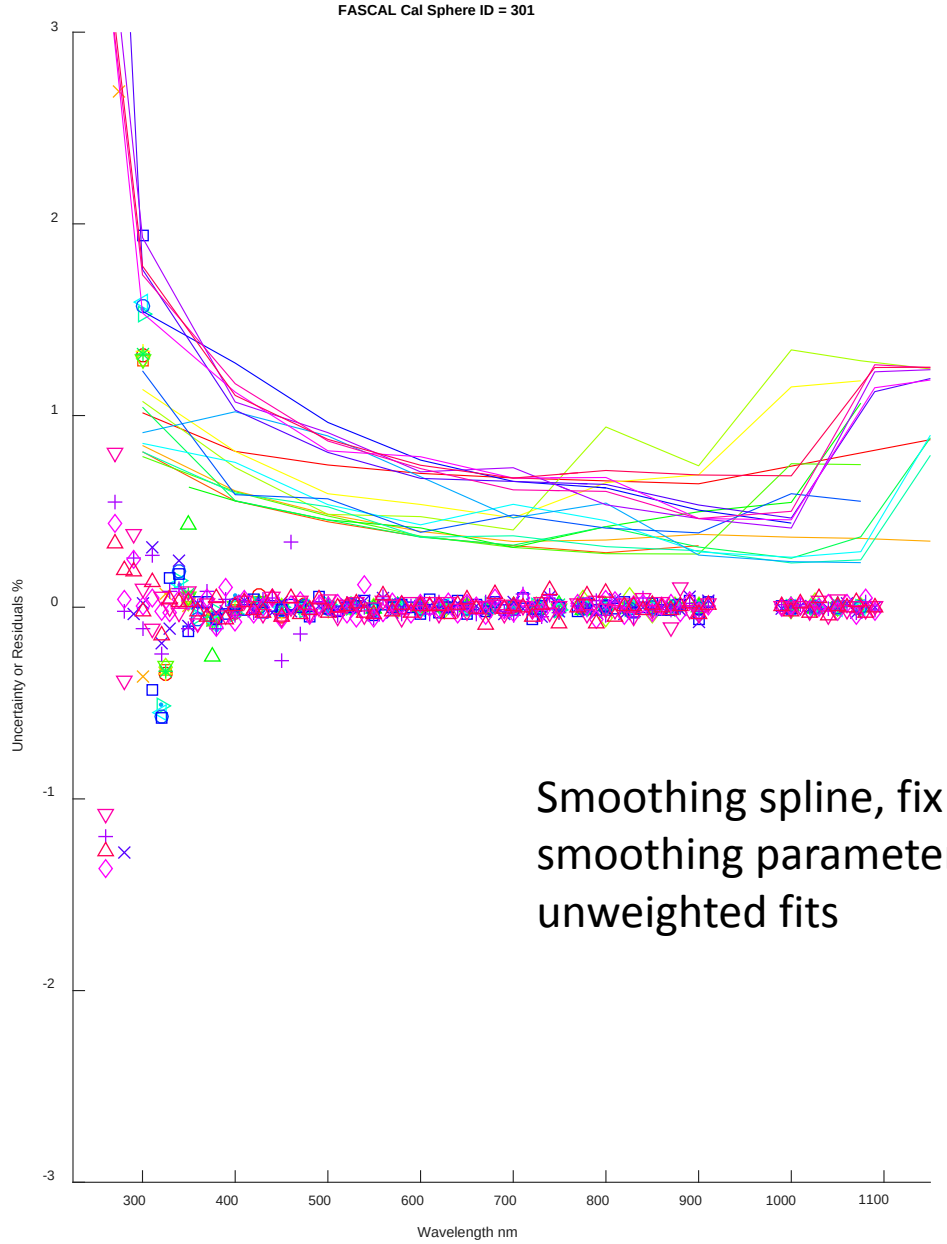




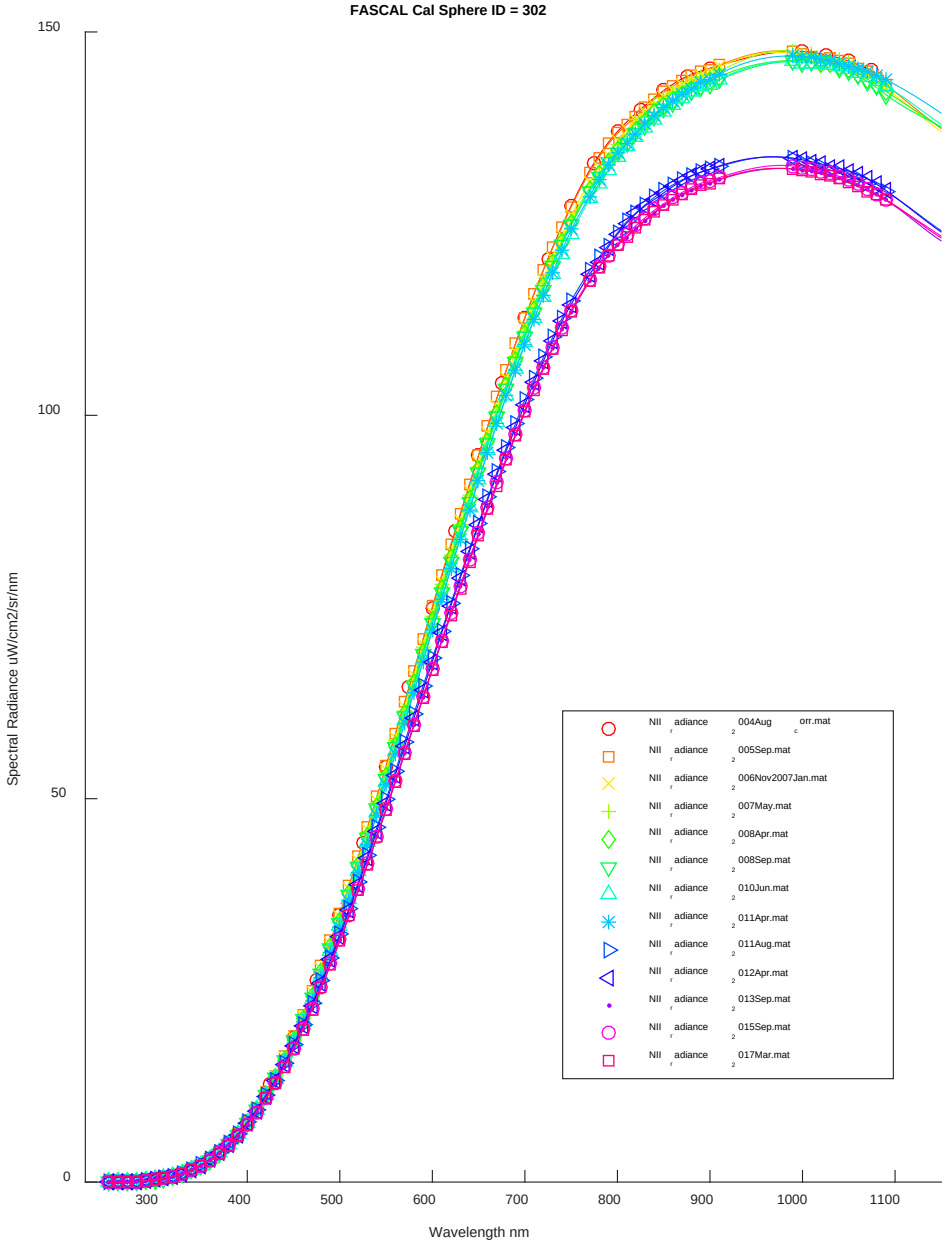


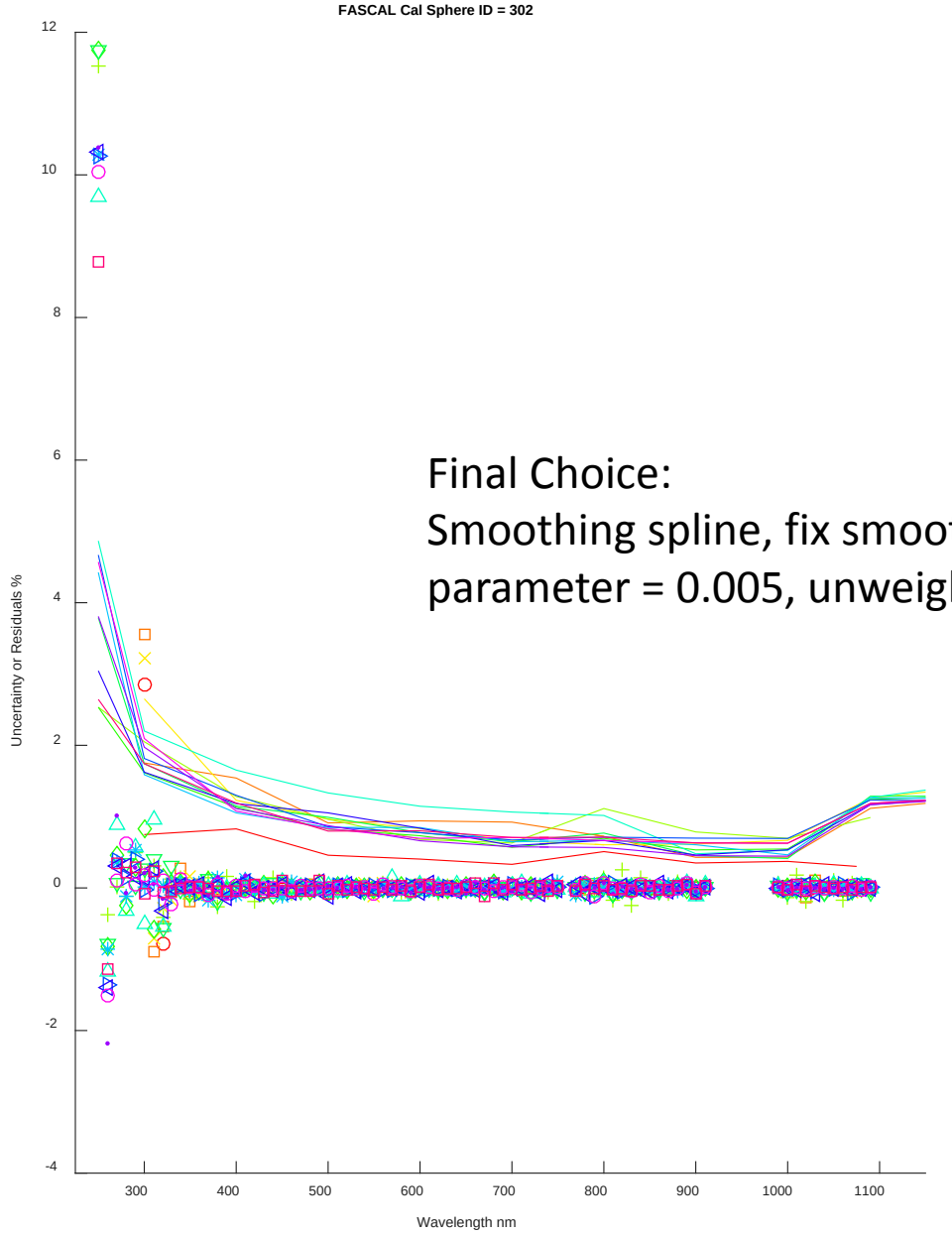
Smoothing spline, fix smoothing parameter not specified, unweighted fits



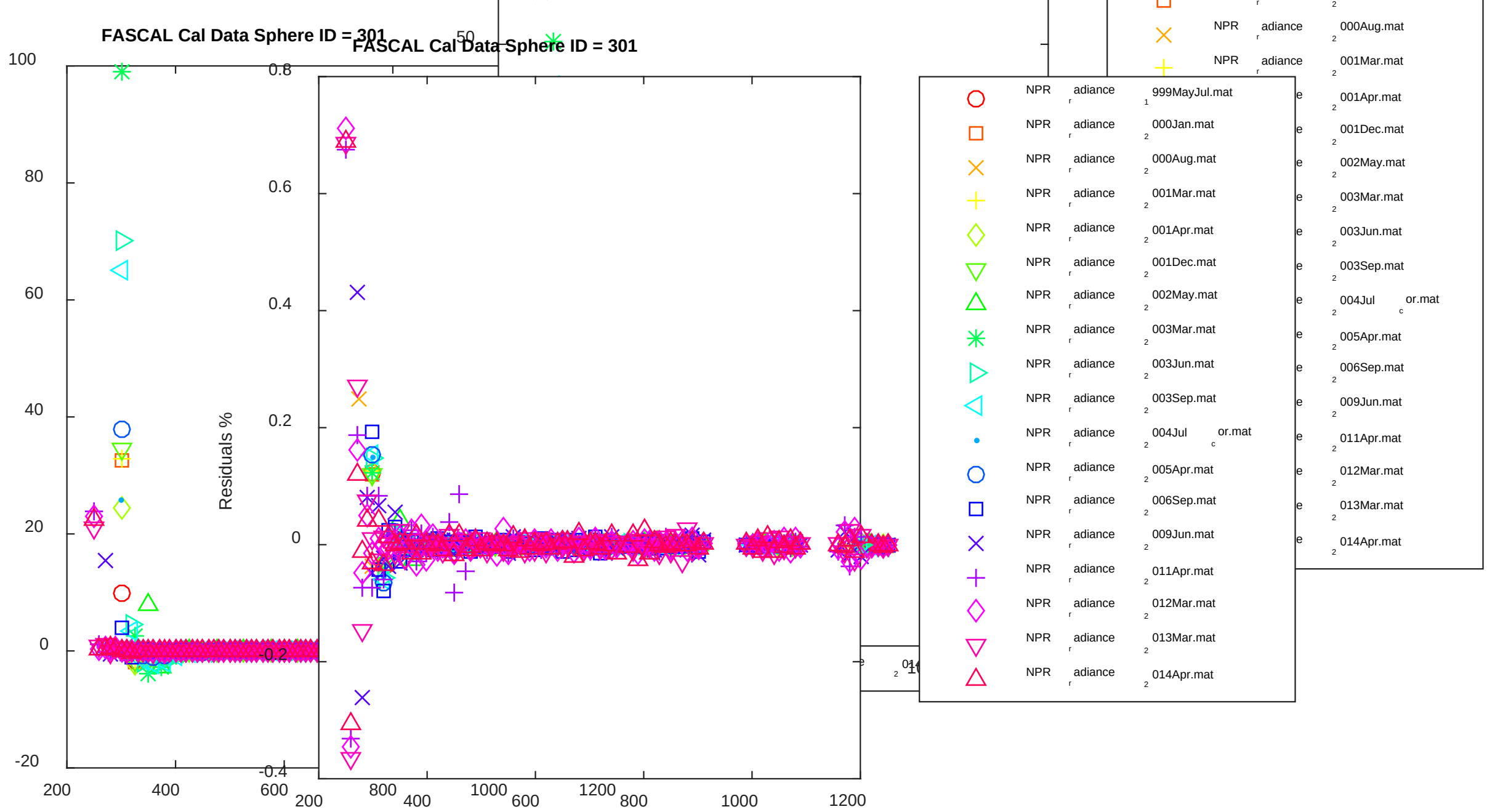


Smoothing spline, fix smoothing parameter = 0.01, unweighted fits

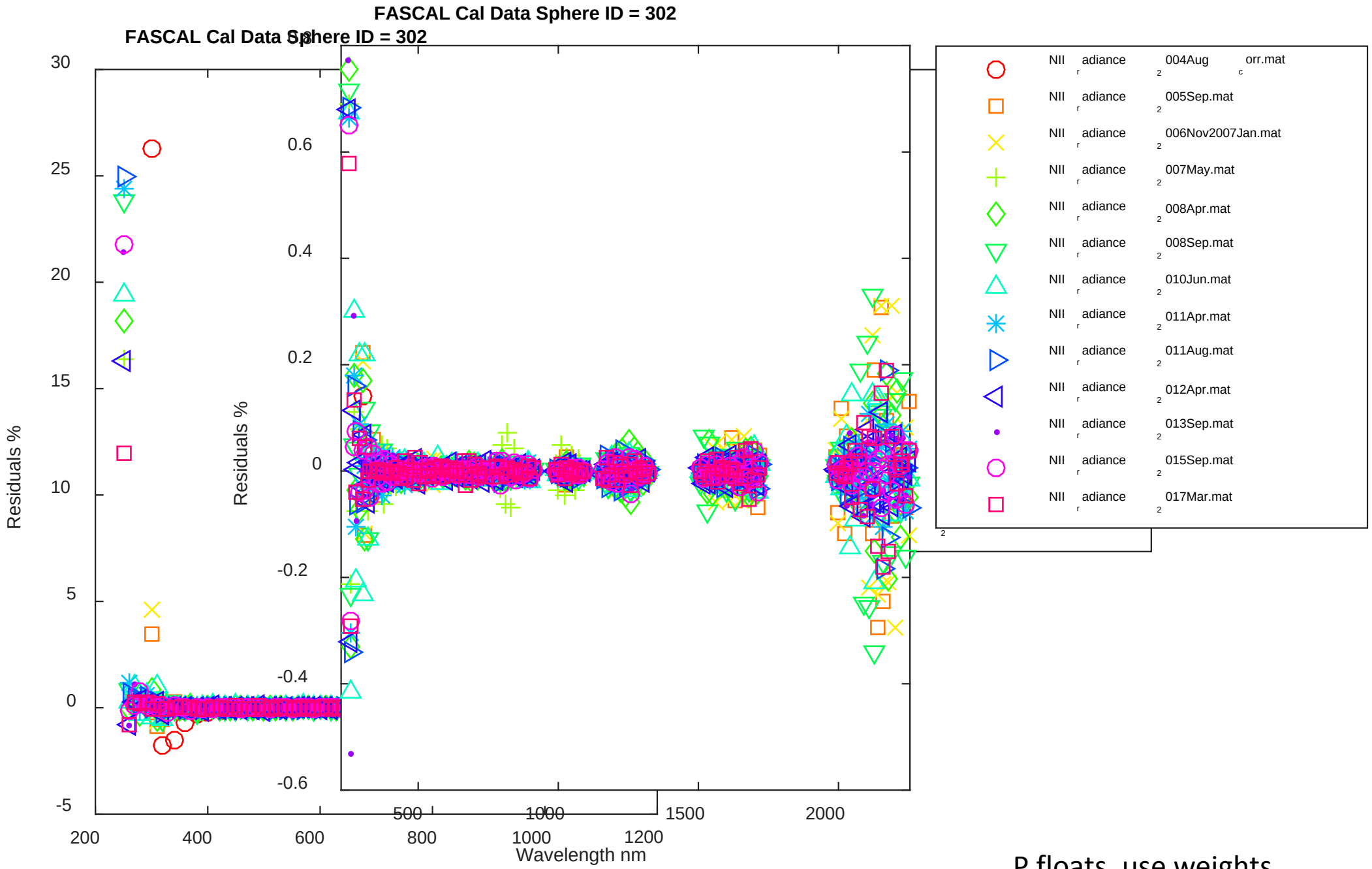




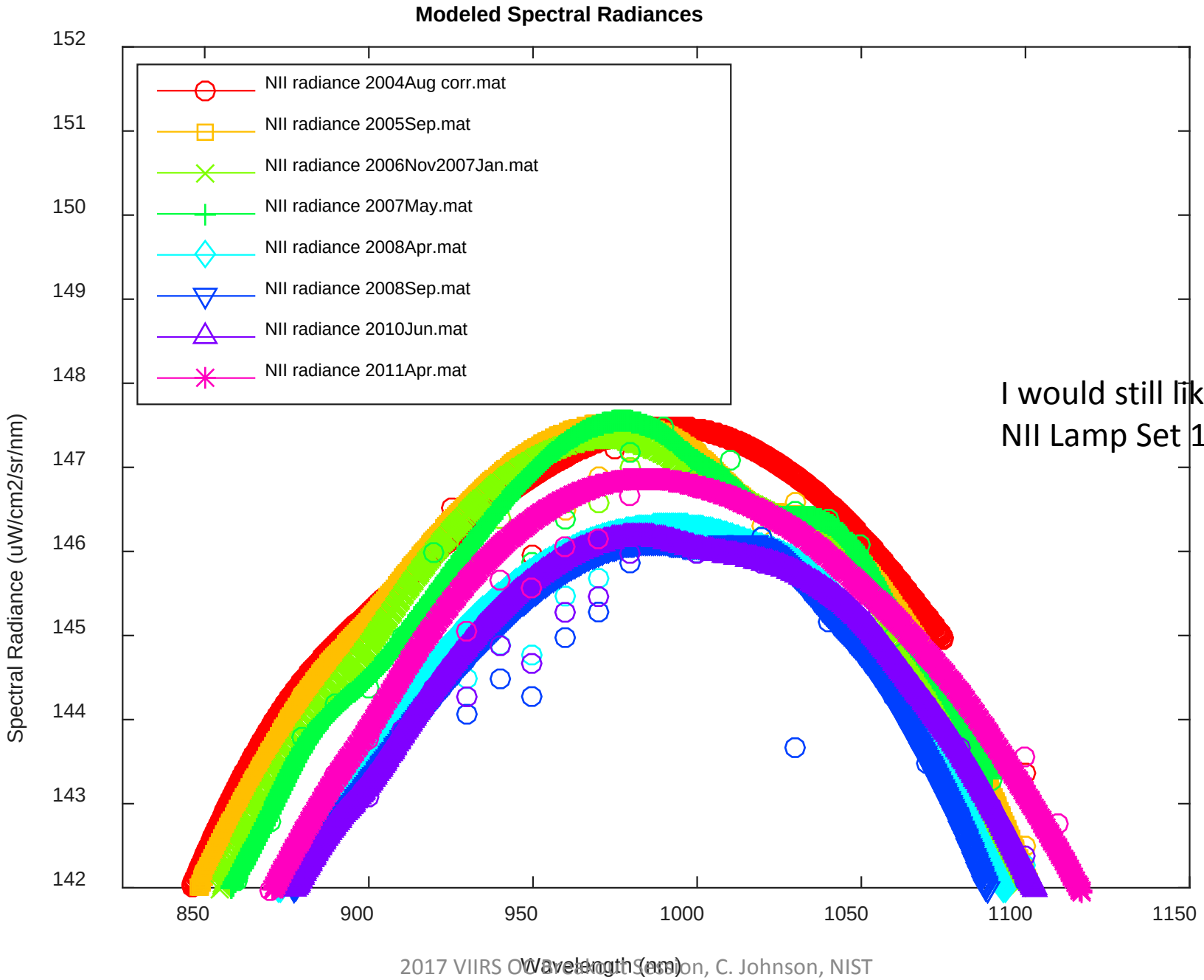
Final Choice:
Smoothing spline, fix smoothing parameter = 0.005, unweighted fits



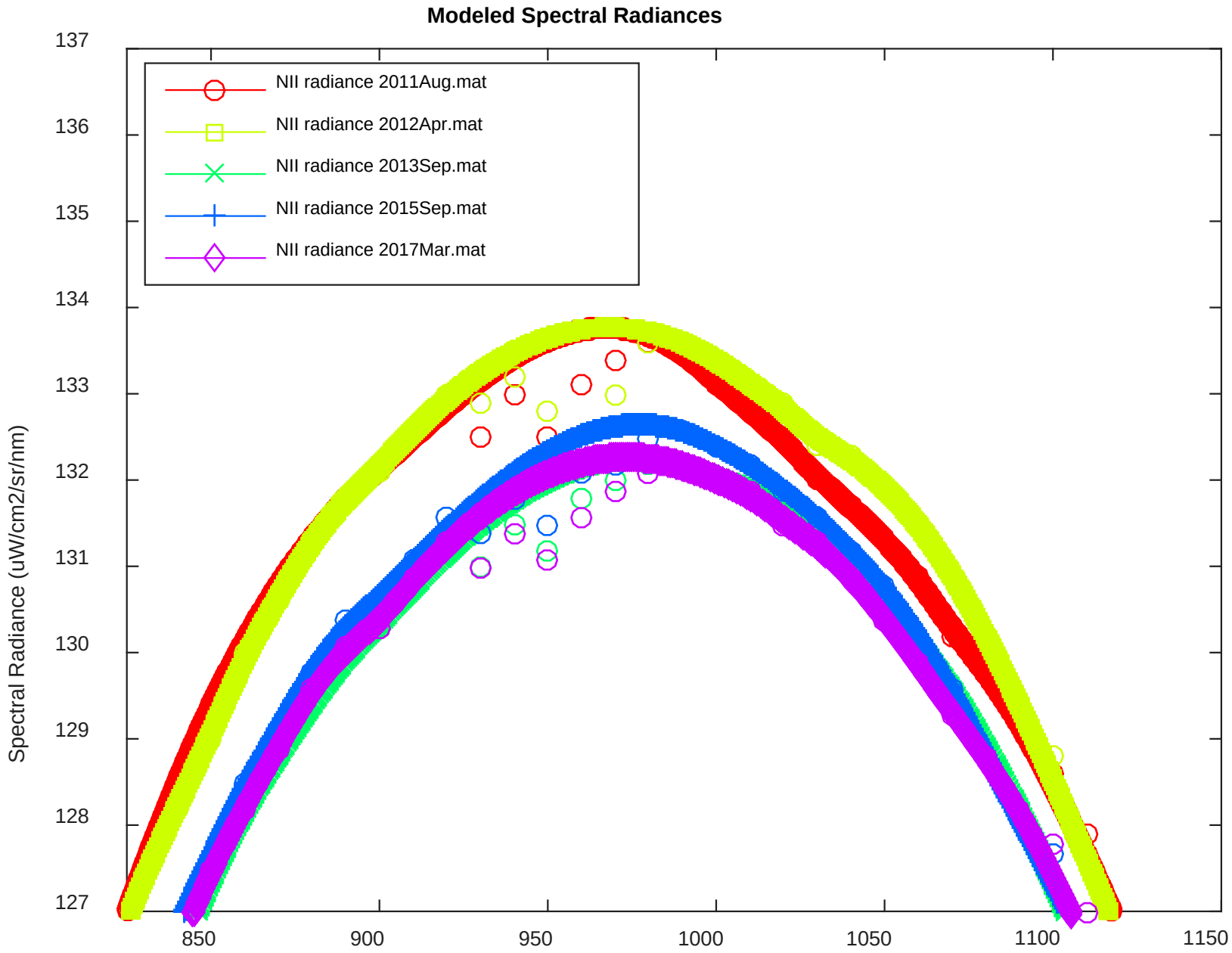
floats, use weights

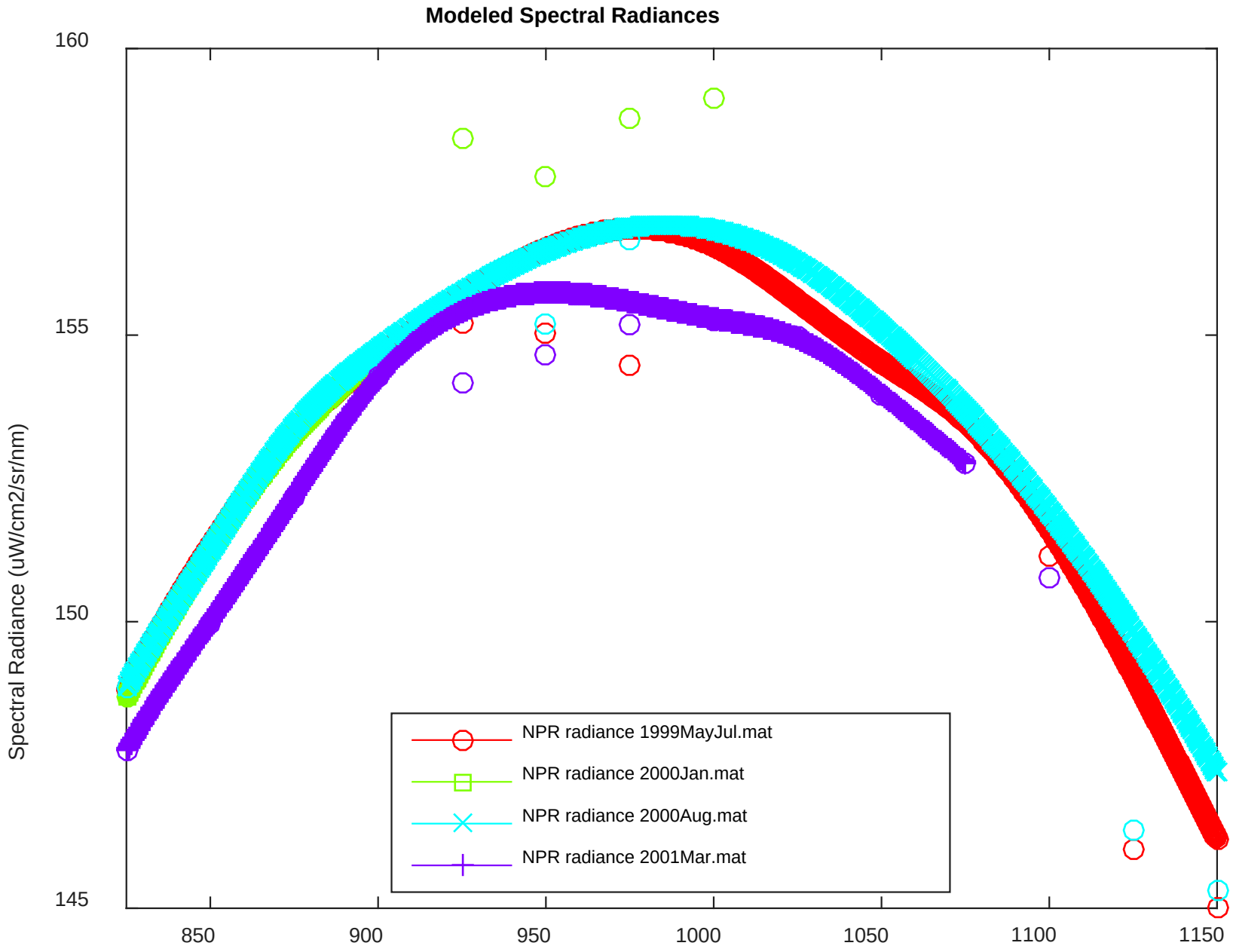


P floats, use weights

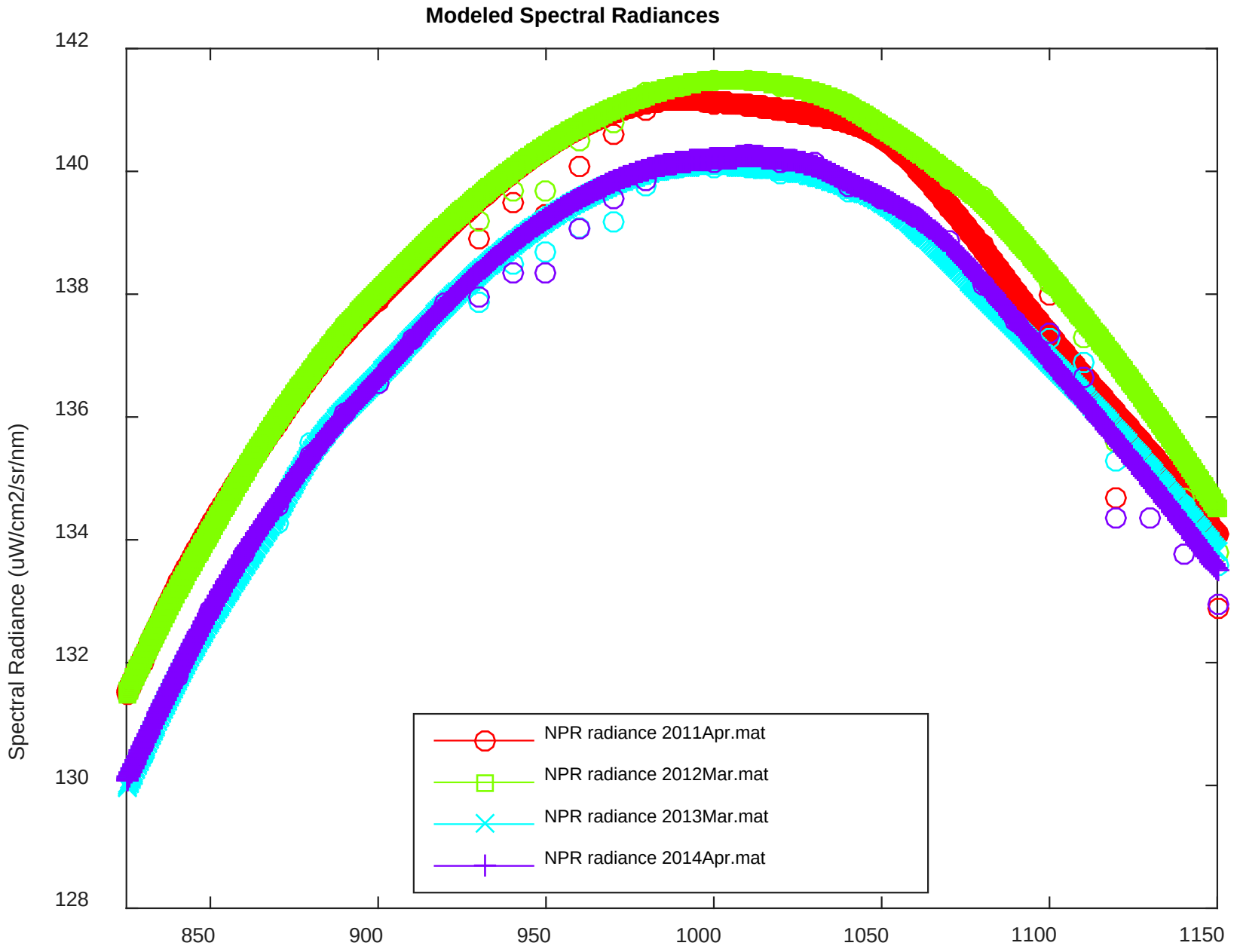


I would still like a physics based model
NII Lamp Set 1


Modeled Spectral Radiances
NII radiance 2011Aug.mat
NII radiance 2012Apr.mat
NII radiance 2013Sep.mat
NII radiance 2015Sep.mat
NII radiance 2017Mar.mat
Spectral Radiance (uW/cm2/sr/nm)
Wavelength (nm)
137
136
135
134
133
132
131
130
129
128
127
850
900
950
1000
1050
1100
1150



Better to have more fascal wavelengths here every 25



Here every 10 nm
Lamp set 4

Phytoplankton functional types, biomass and photosynthetic competency in the mid-Atlantic Bight following hurricane Matthew

Esther Kang, Kali McKee, Helga do R. Gomes, Joaquim I. Goes

Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE

Zhongping Lee & Jianwei Wei

UMASS BOSTON
UNIVERSITY OF MASSACHUSSETTS BOSTON

Chuanmin Hu, Shaojie Sun David English

USF UNIVERSITY OF SOUTH FLORIDA

COLUMBIA UNIVERSITY

NOAA NESDIS STAR Center for Satellite Applications and Research
Weather and Water
SMC
CORP
Climate
Ecosystems
Commerce
SOC

BARNARD

BROAD OBJECTIVES

Examine the distribution and photo-physiology of phytoplankton functional types (PFTs) in the Mid-Atlantic Bight shelf region using high resolution flow through measurements

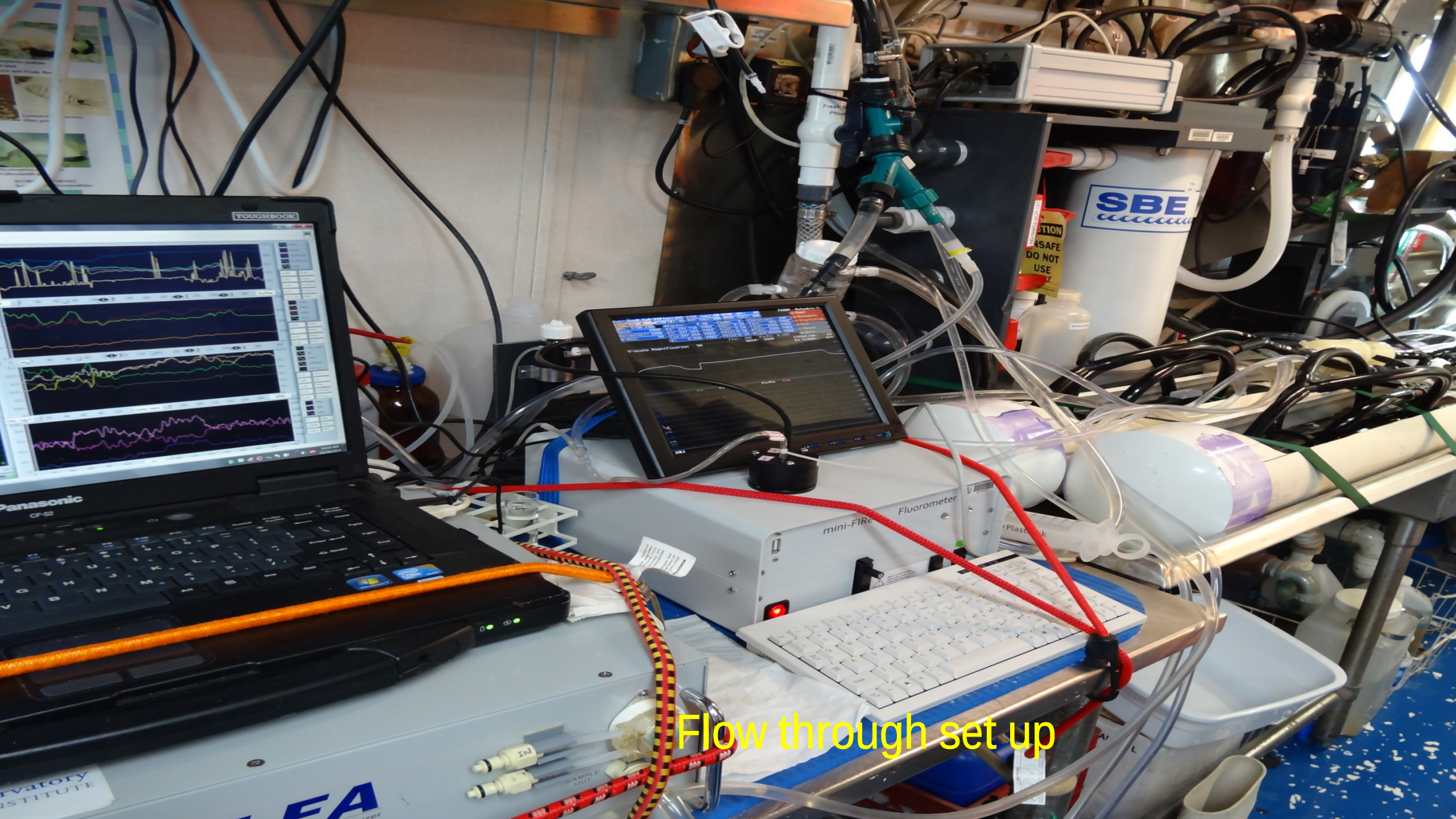
Examine the potential of flow through measurements for enhancing the utility of satellite ocean color for PFT biomass and productivity estimates

FLOW-THROUGH SETUP

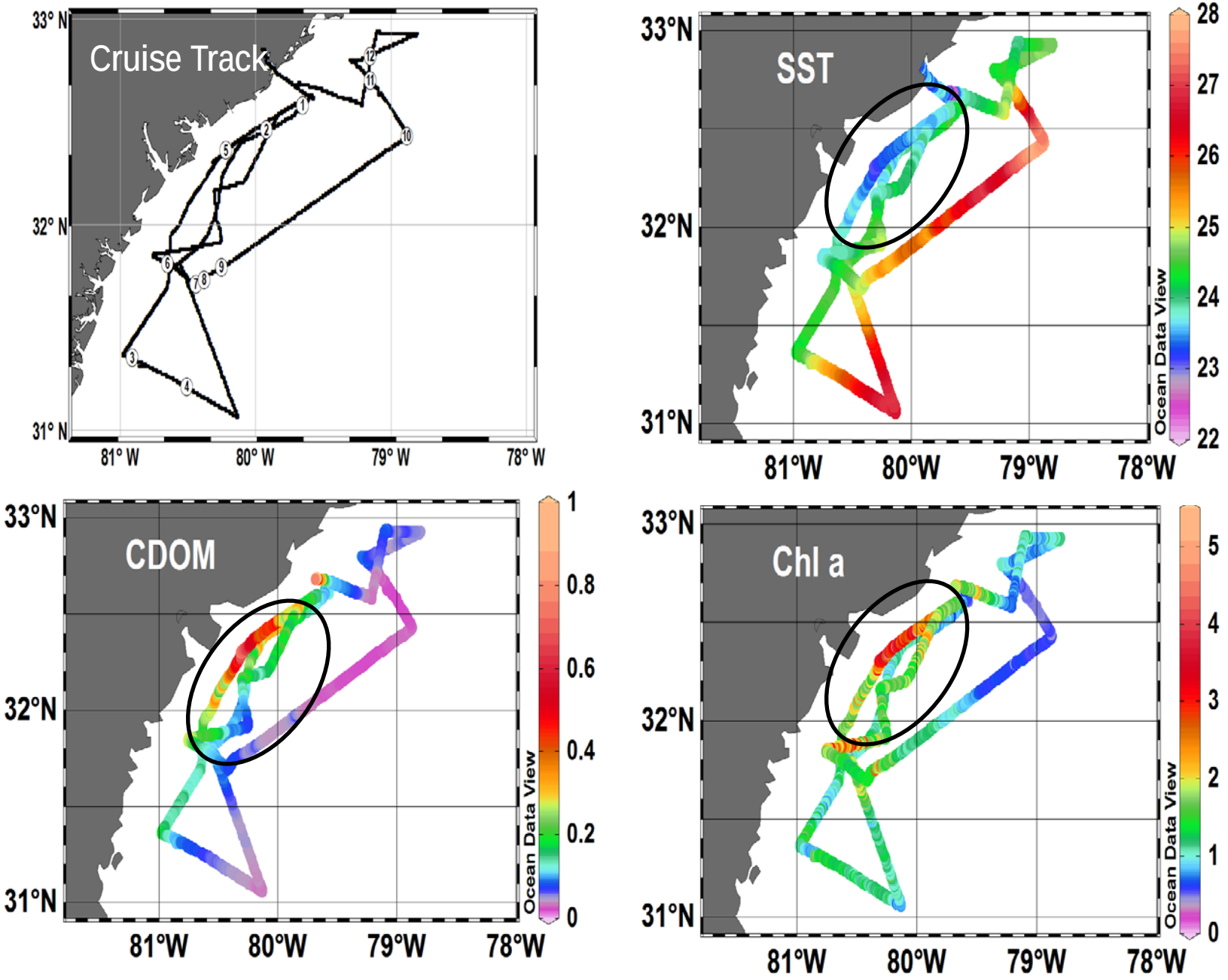
- Automated Laser Fluorometer (Chl *a*, CDOM, PE-1, PE-2, PE-3, Fv/Fm, NPQ, PQ)
- Satlantic FIRe (Chl *a*, Fv/Fm, sPSII)
- bbe-Moldaenke (Chl a - Diatoms, Cryptophytes, Green Algae, Cyanobacteria)
- FlowCAM (Phytoplankton imaging, taxonomy and size classification)

o WATER COLUMN MEASUREMENTS

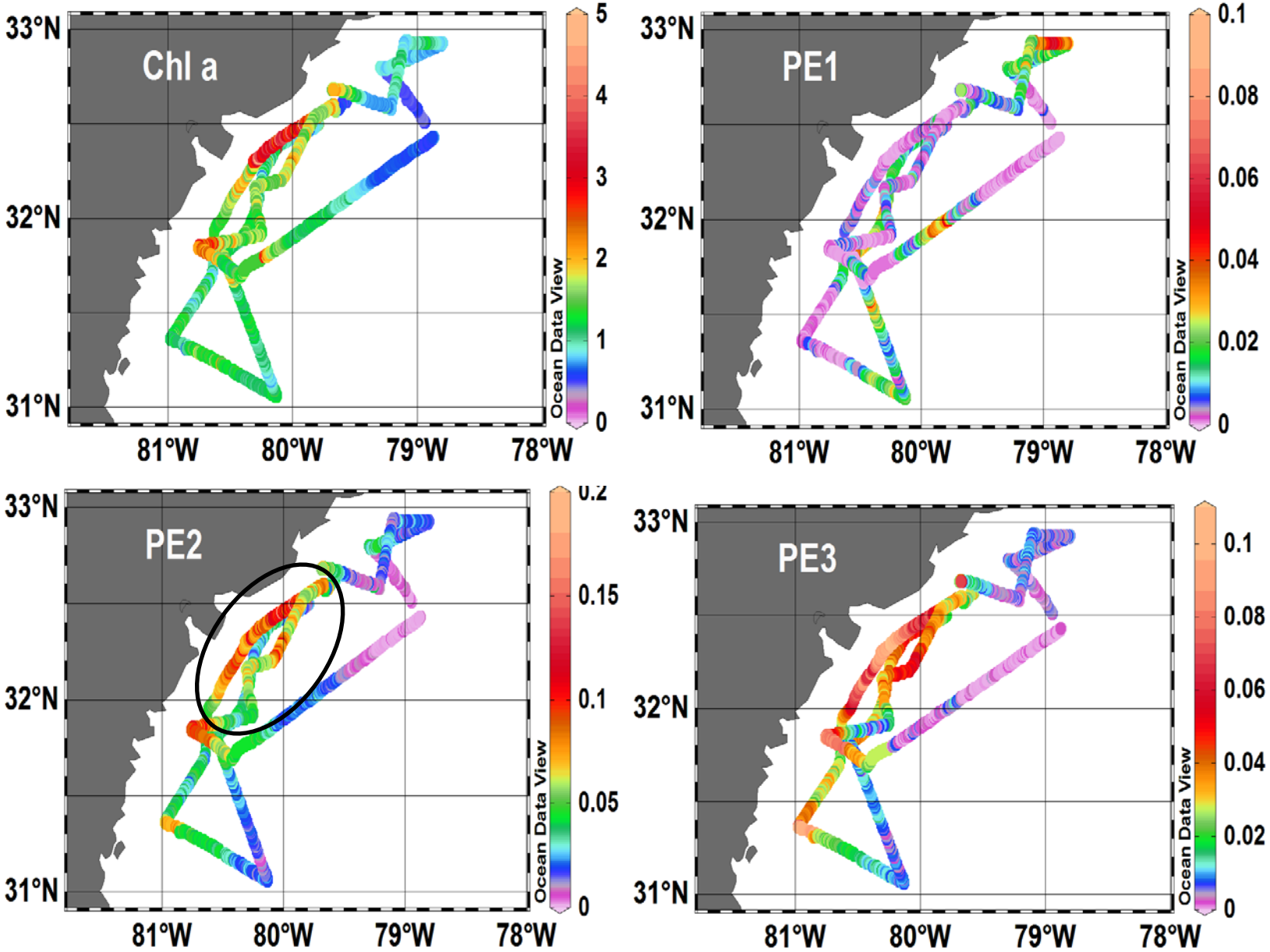
- Automated Laser Fluorometer (Chl *a*, CDOM, PE-1, PE-2, PE-3, Fv/Fm, sPSI)
- Satlantic FIRe (Chl *a*, Fv/Fm, sPSII, Electron Transport Reactions)
- FlowCAM (Phytoplankton imaging, taxonomy and size classification)
- Phycobilipigment estimates in seawater



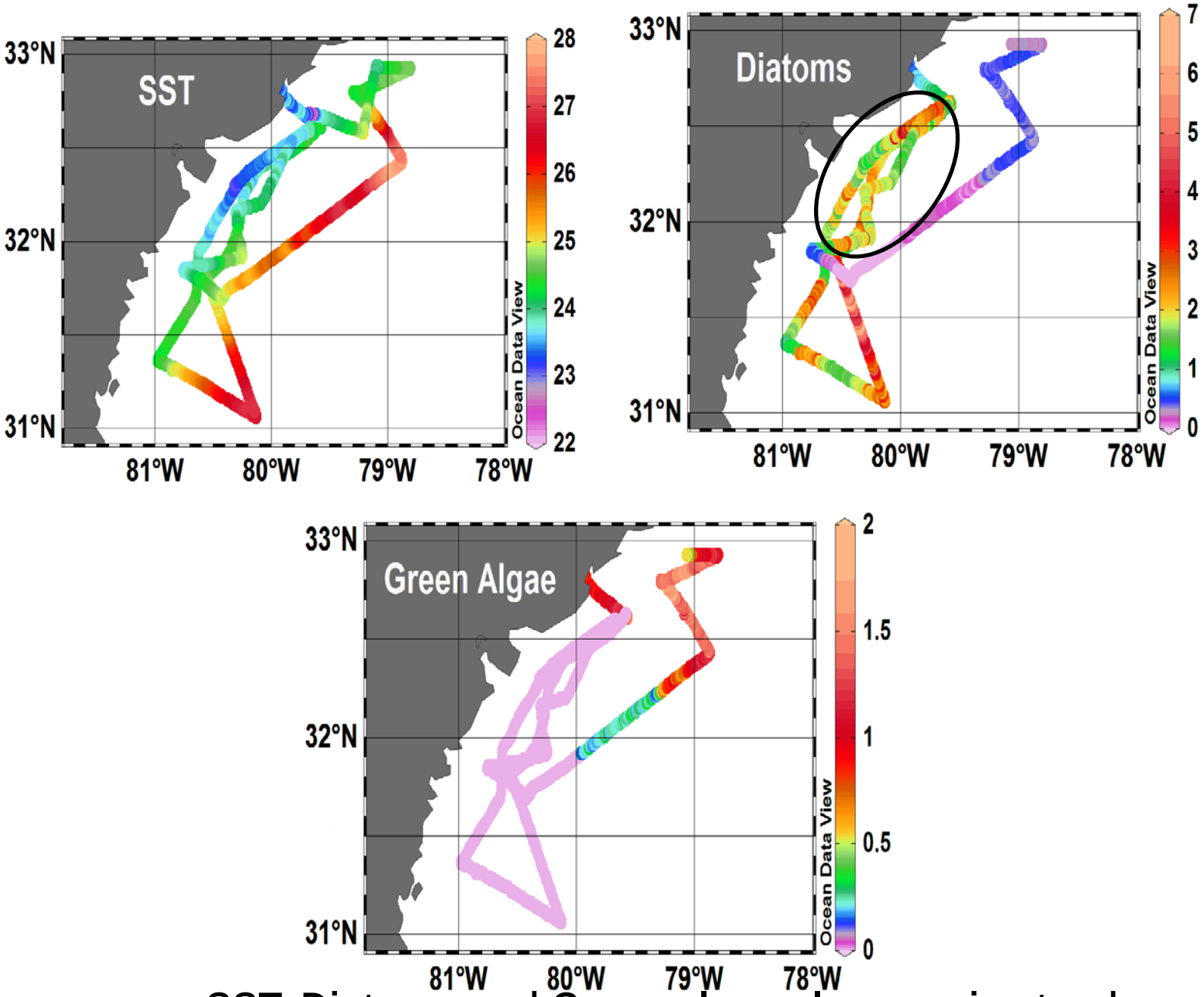
Flow through set up



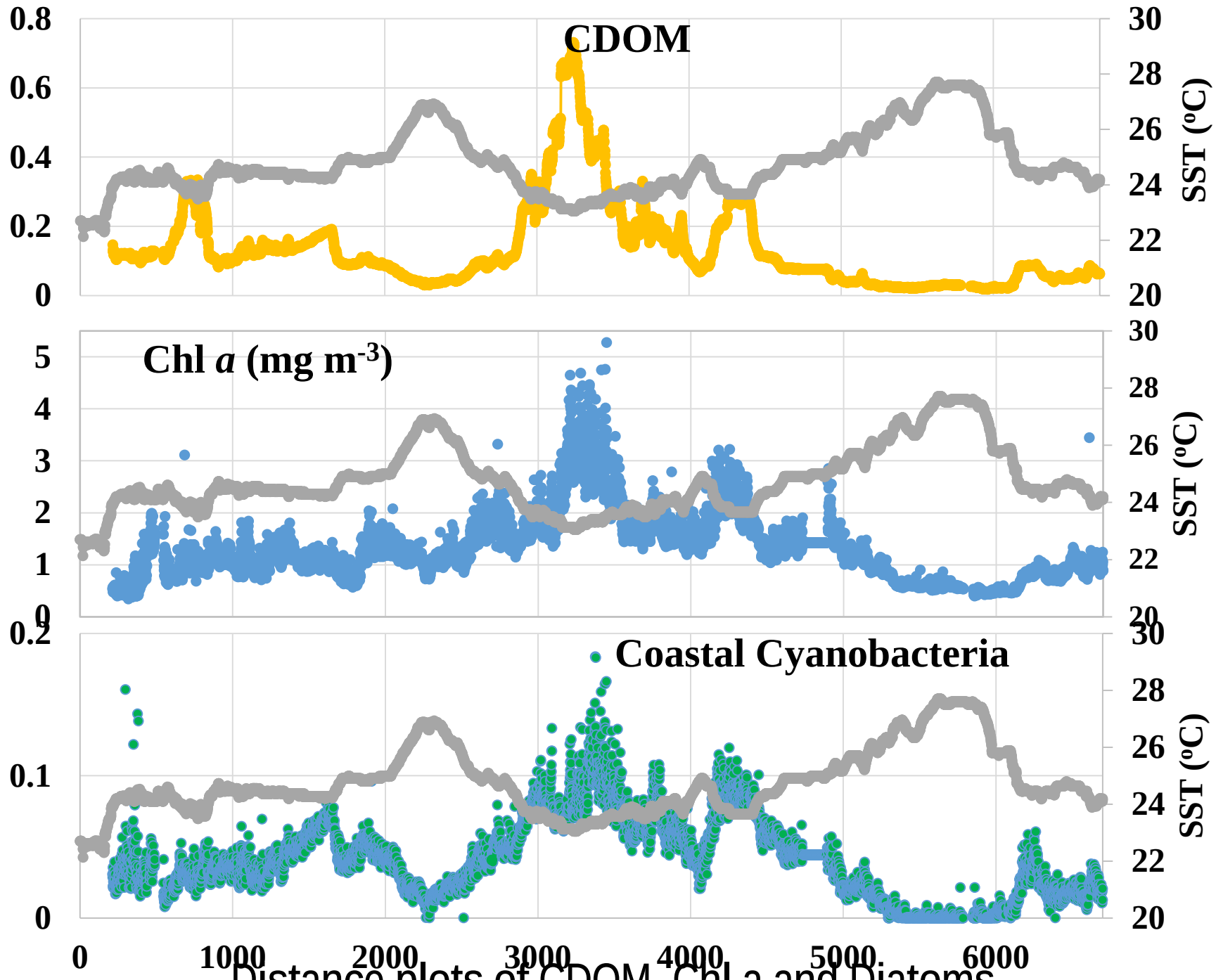
SST, CDOM and Chl *a*, along cruise track



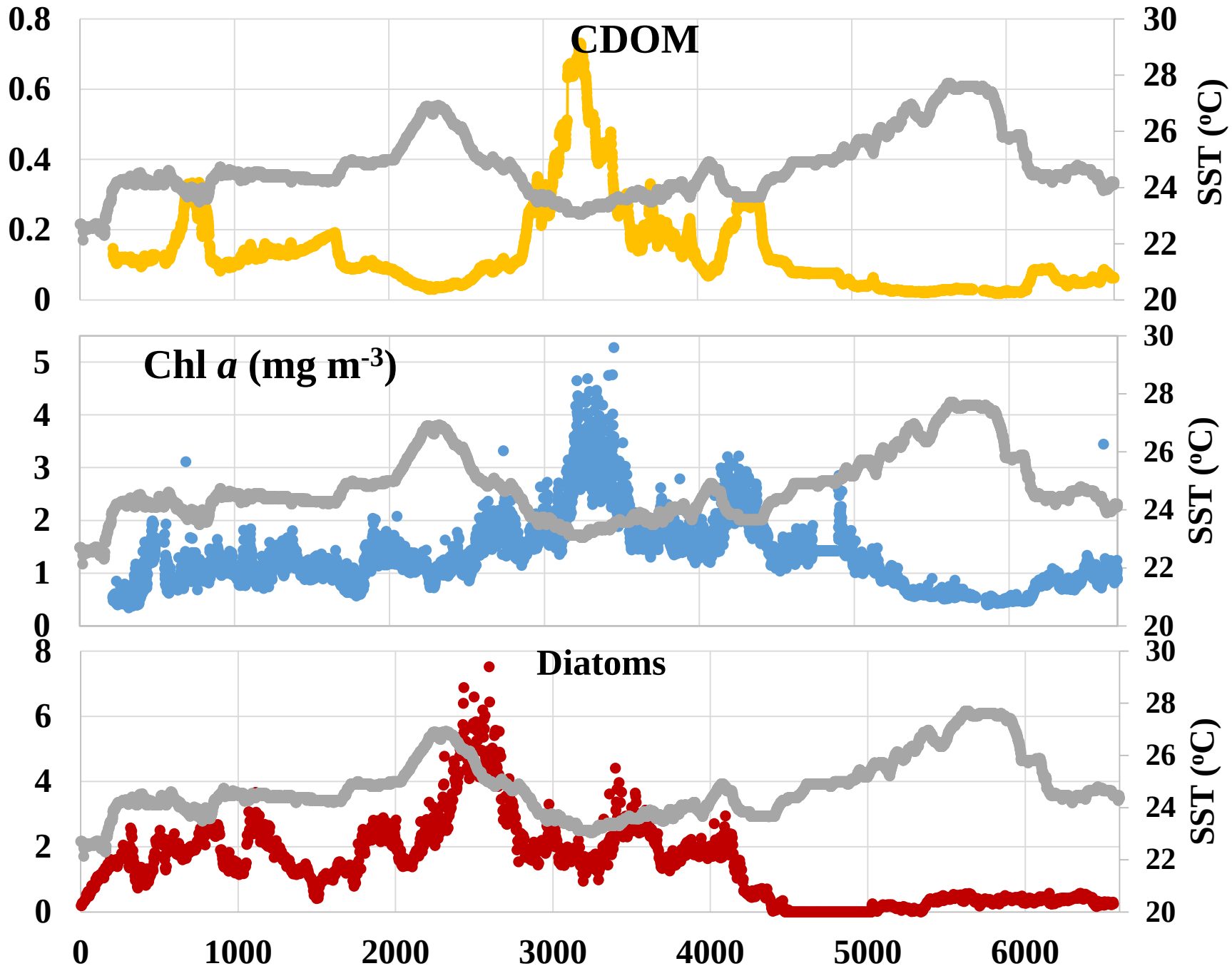
Distribution of Chl *a*, blue water cyanobacteria, coastal water cyanobacteria, Cryptophytes along cruise track



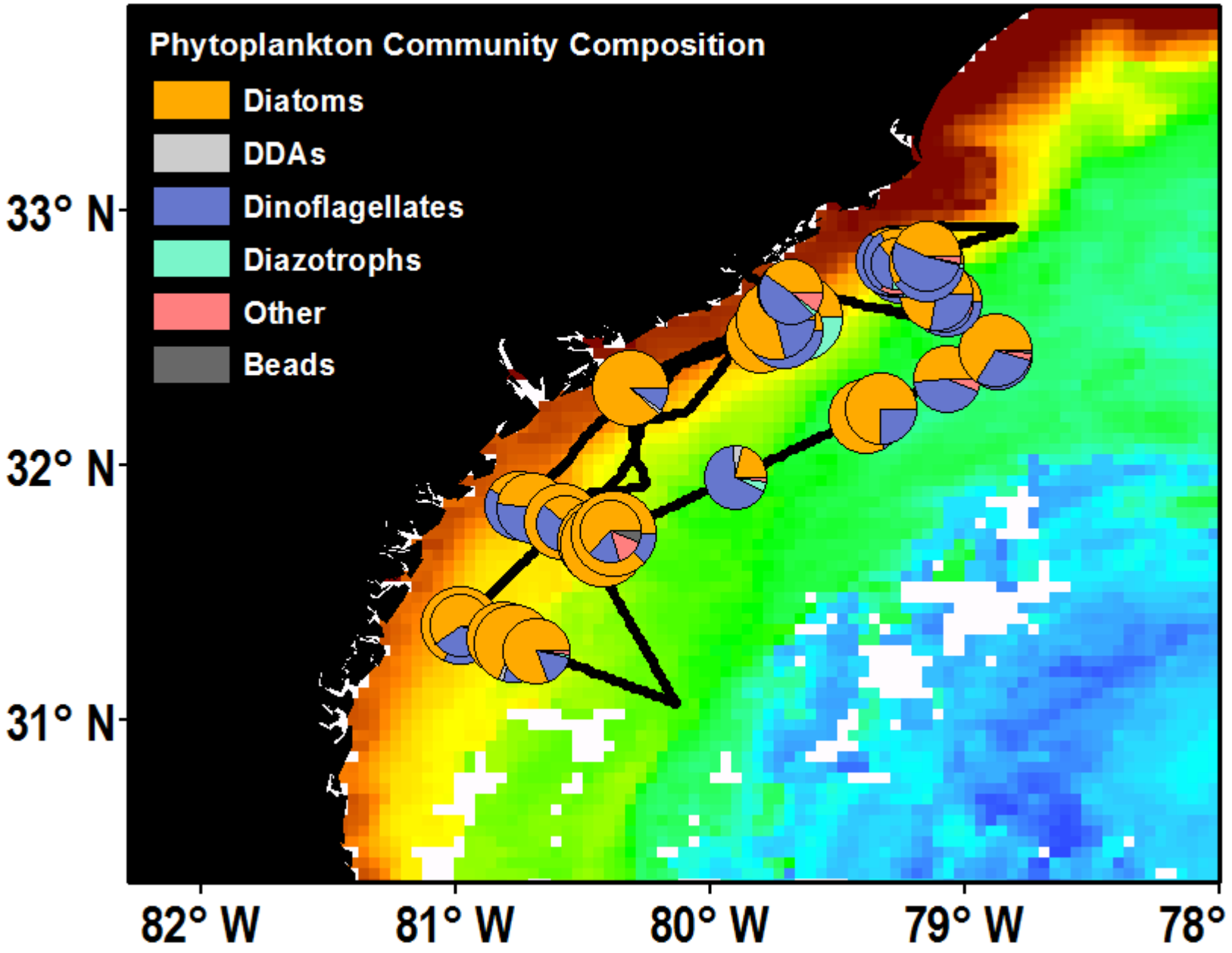
SST, Diatoms and Green algae along cruise track



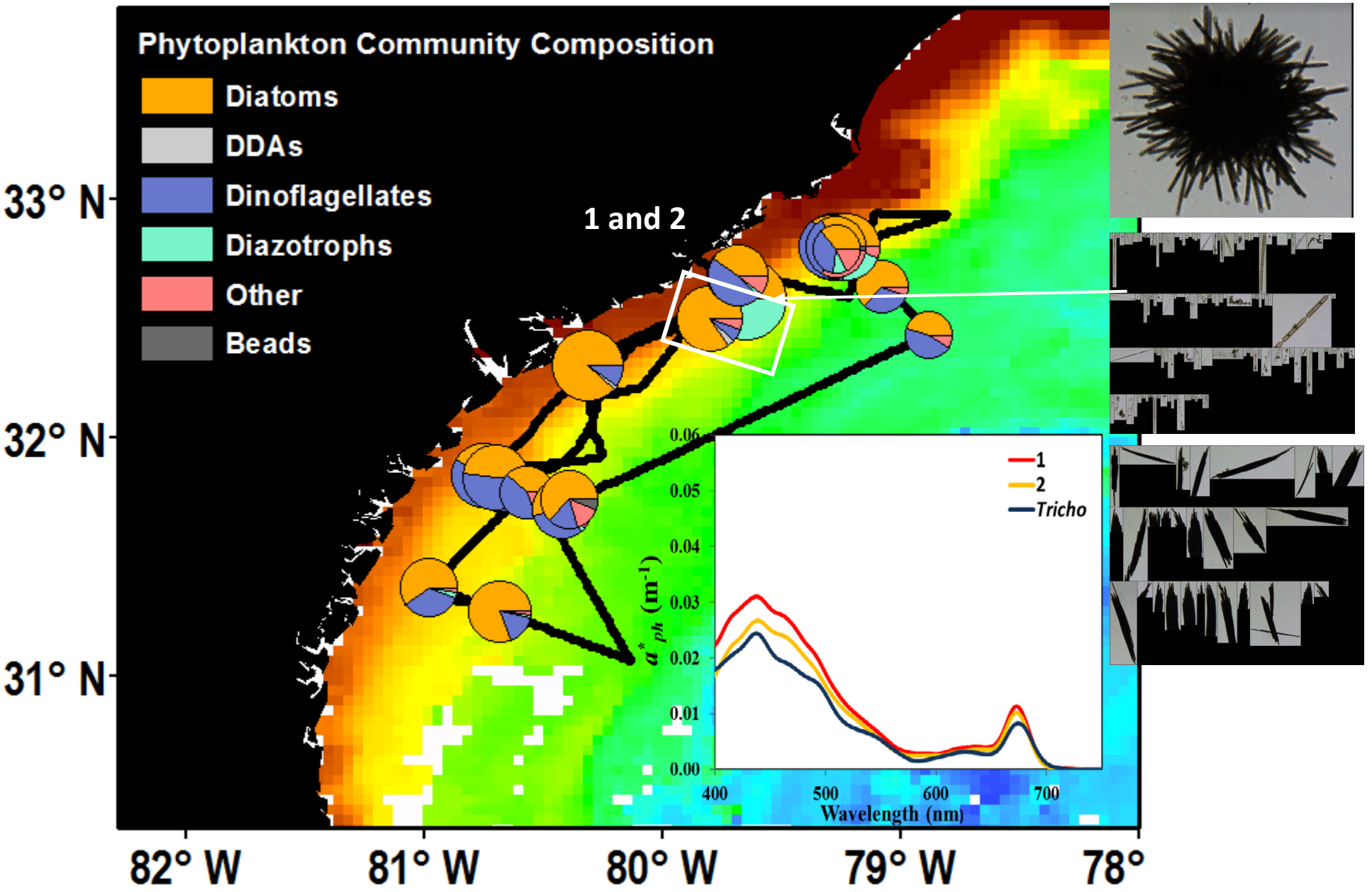
Distance plots of CDOM, Chl a and Diatoms



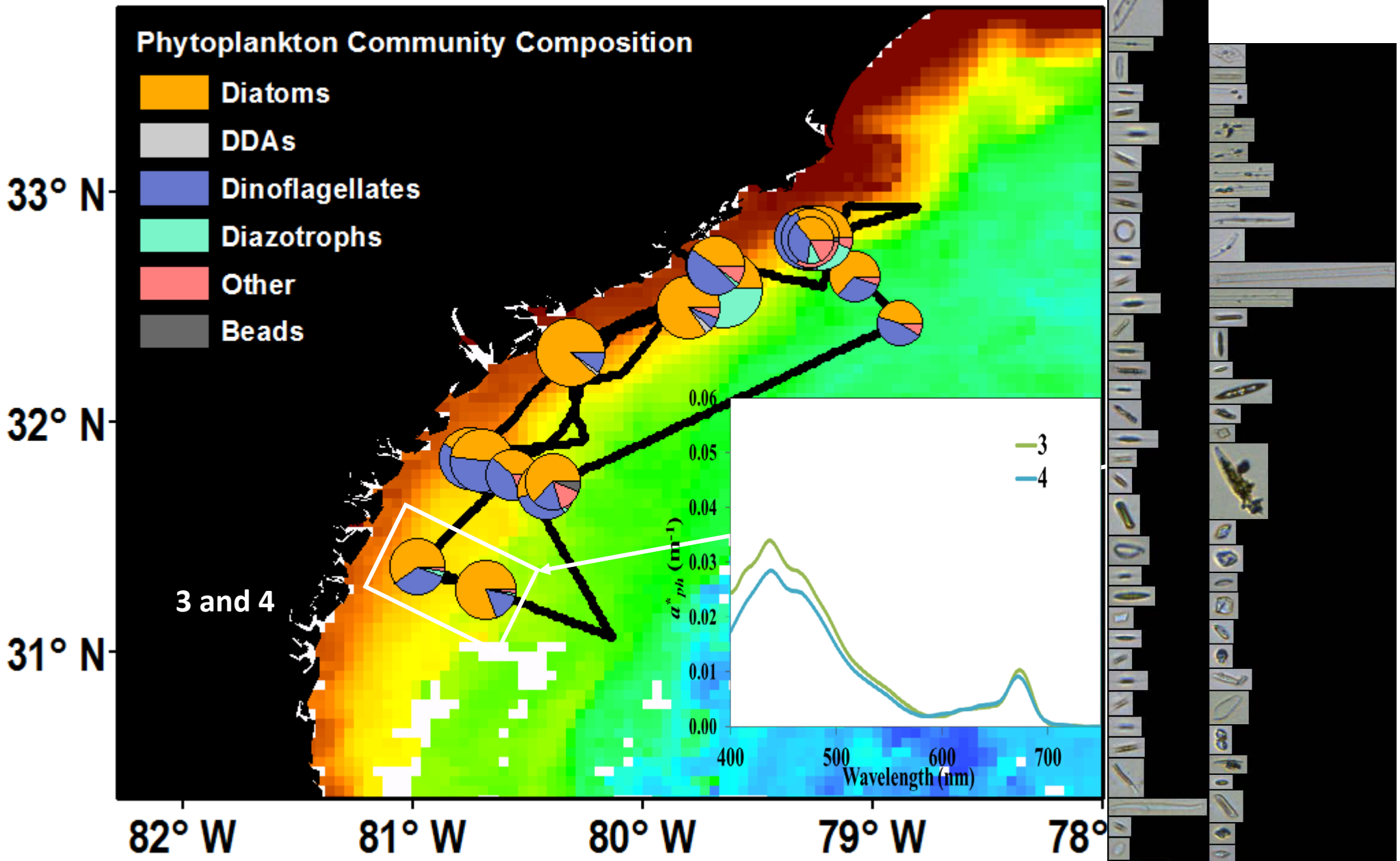
Distance plots of CDOM, Chl a and Diatoms



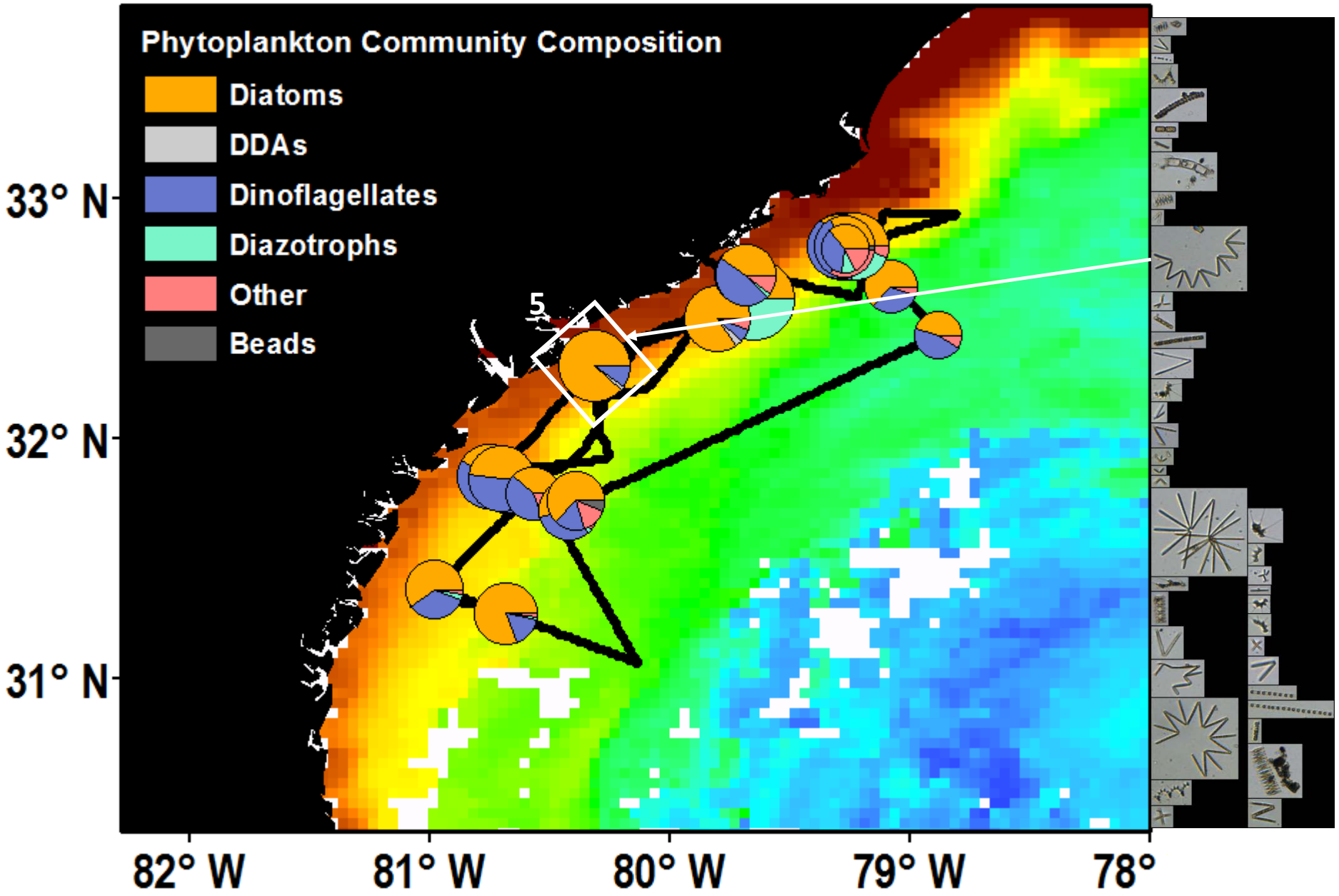
Distribution of major PFTs – Oct 2016



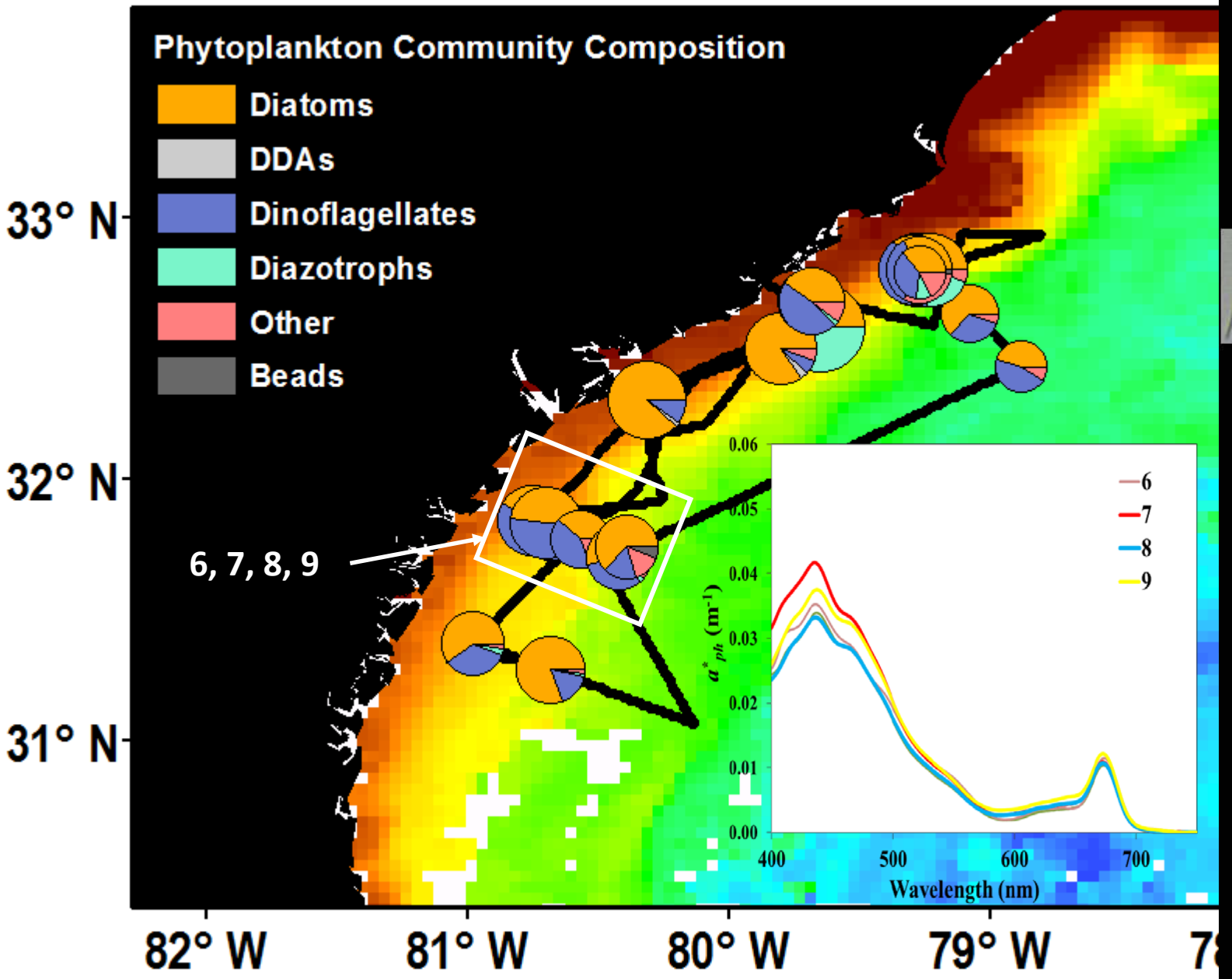
Distribution of major PFTs at stations 1 & 2

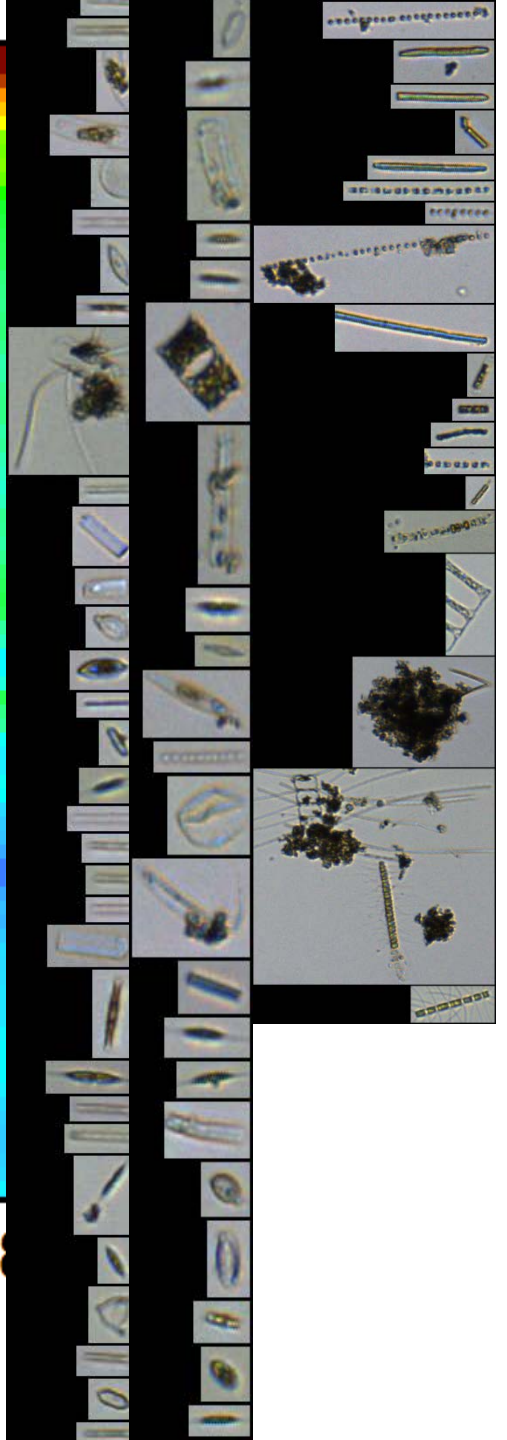


Distribution of major PFTs at stations 3 & 4

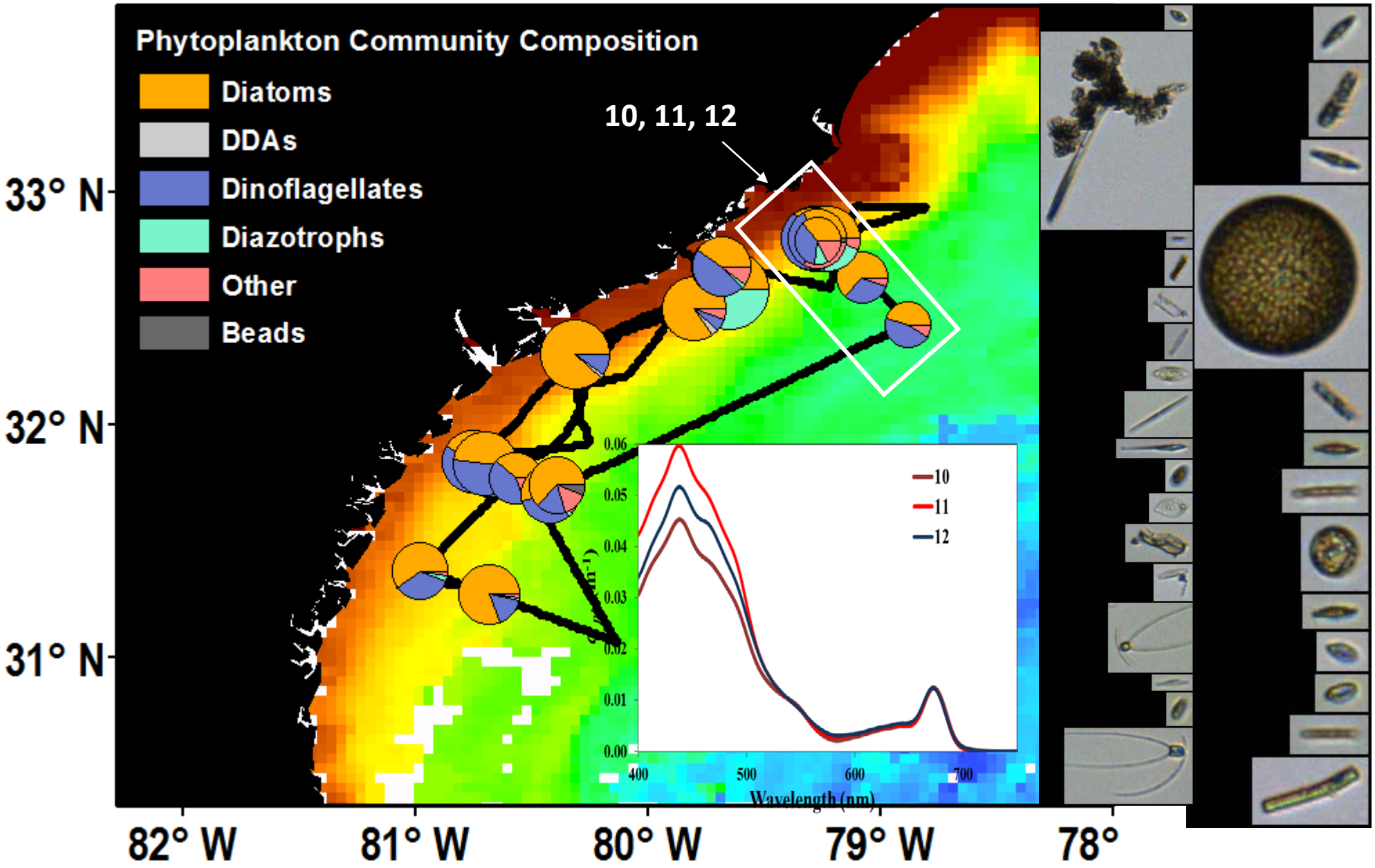


Distribution of major PFTs at station 5

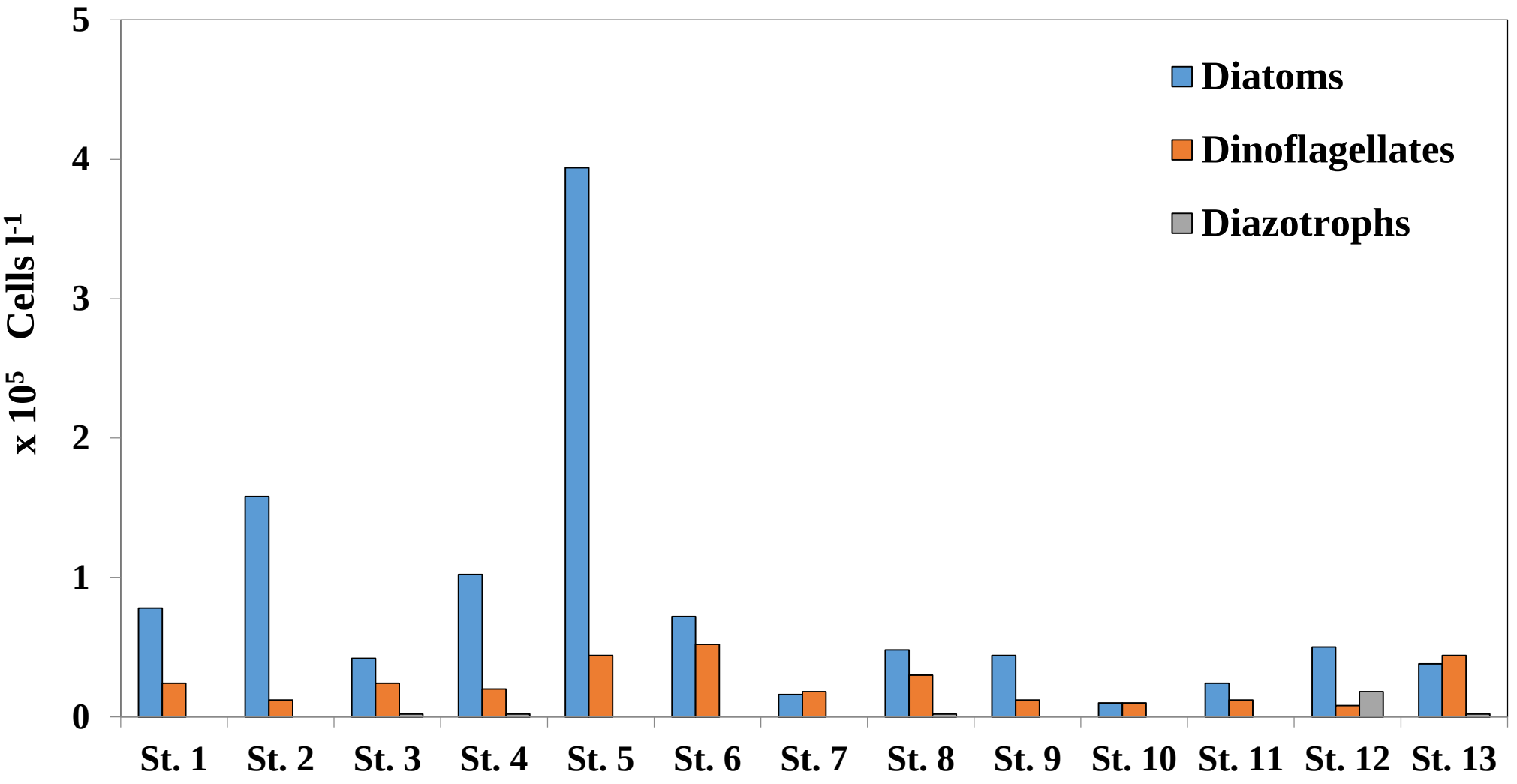




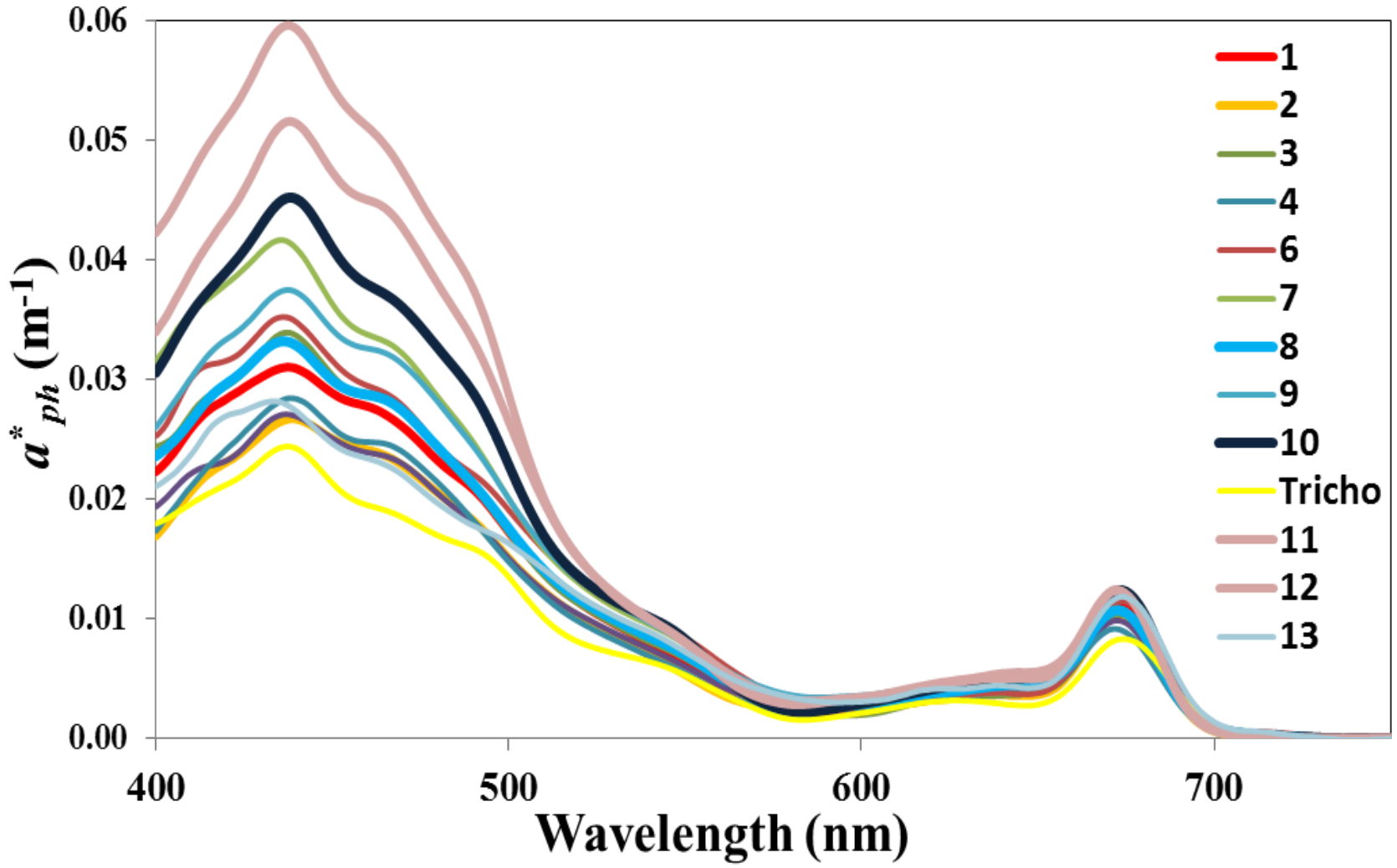
Distribution of major PFTs at stations 6, 7, 8, 9



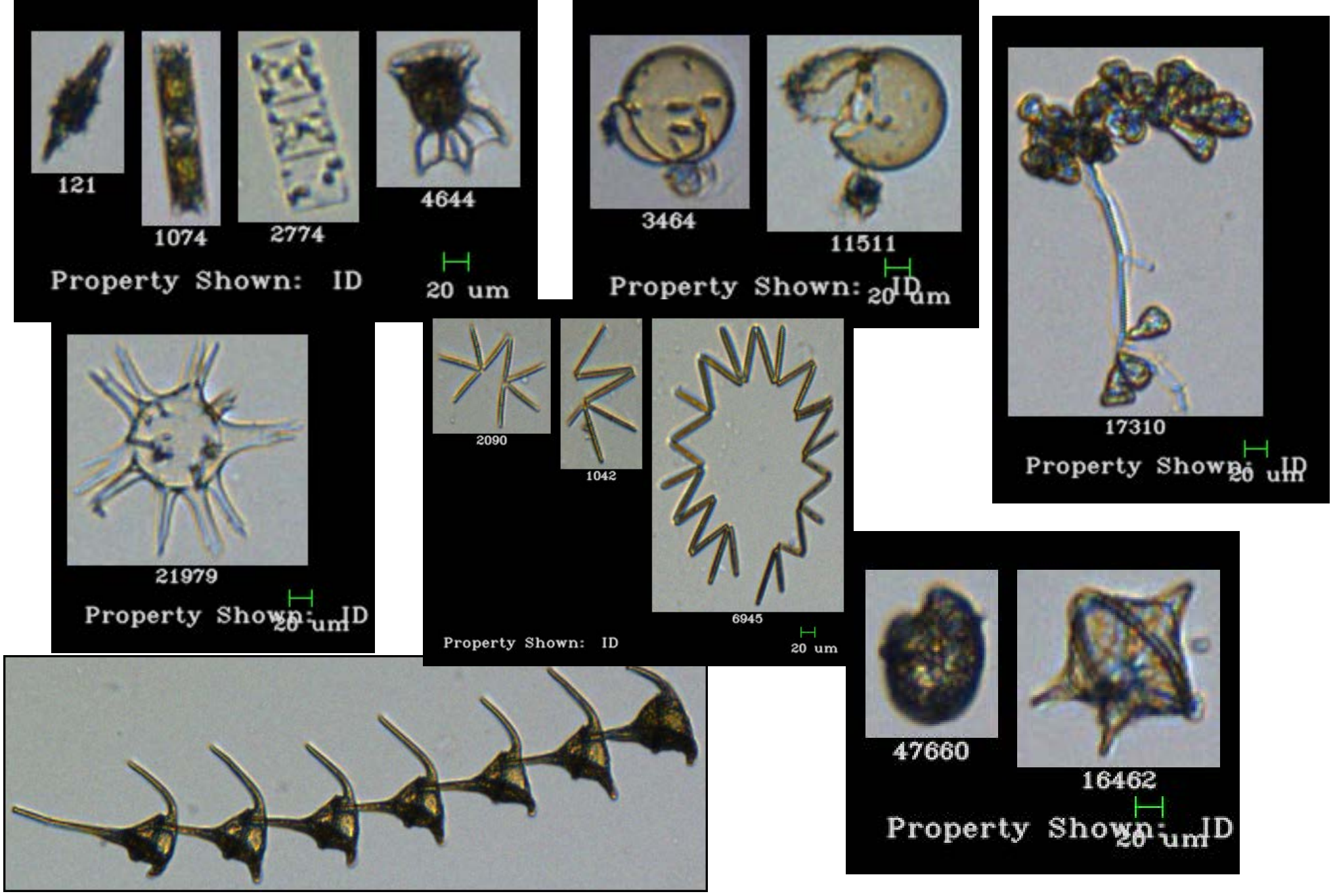
Distribution of major PFTs at stations 10, 11 & 12



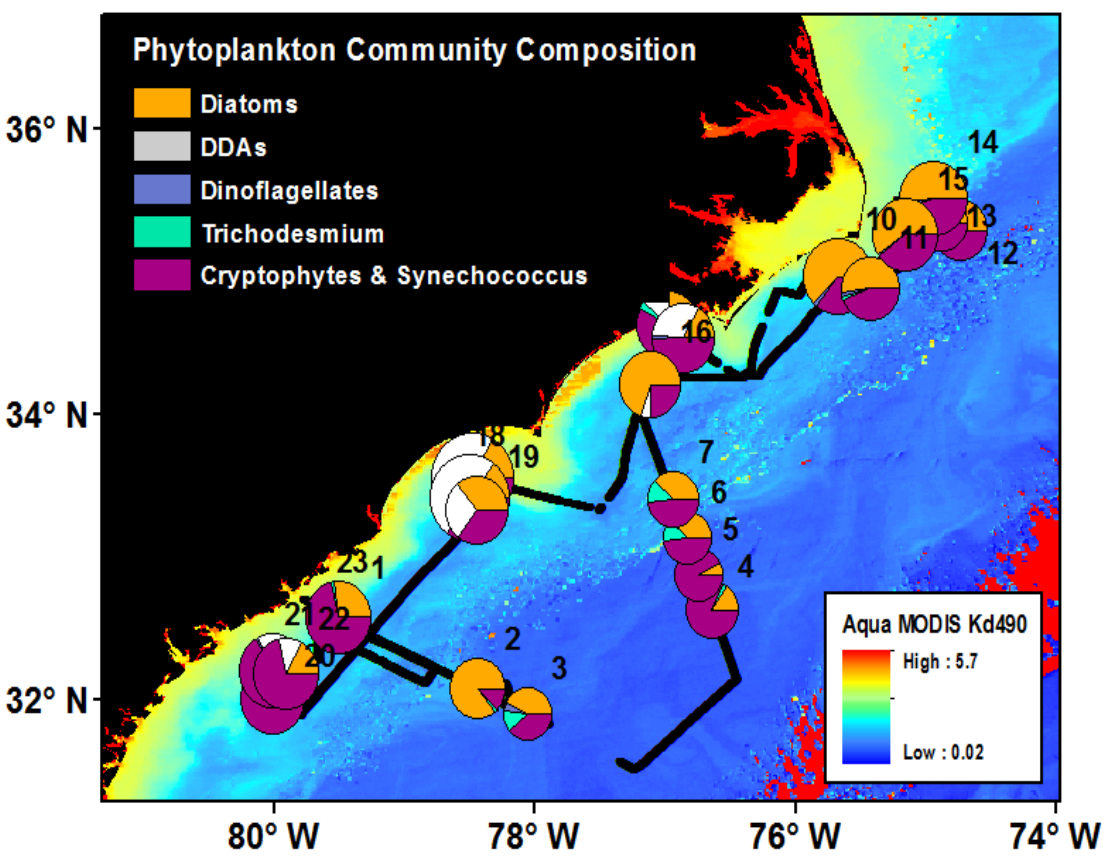
Composition of PFTs at discrete stations

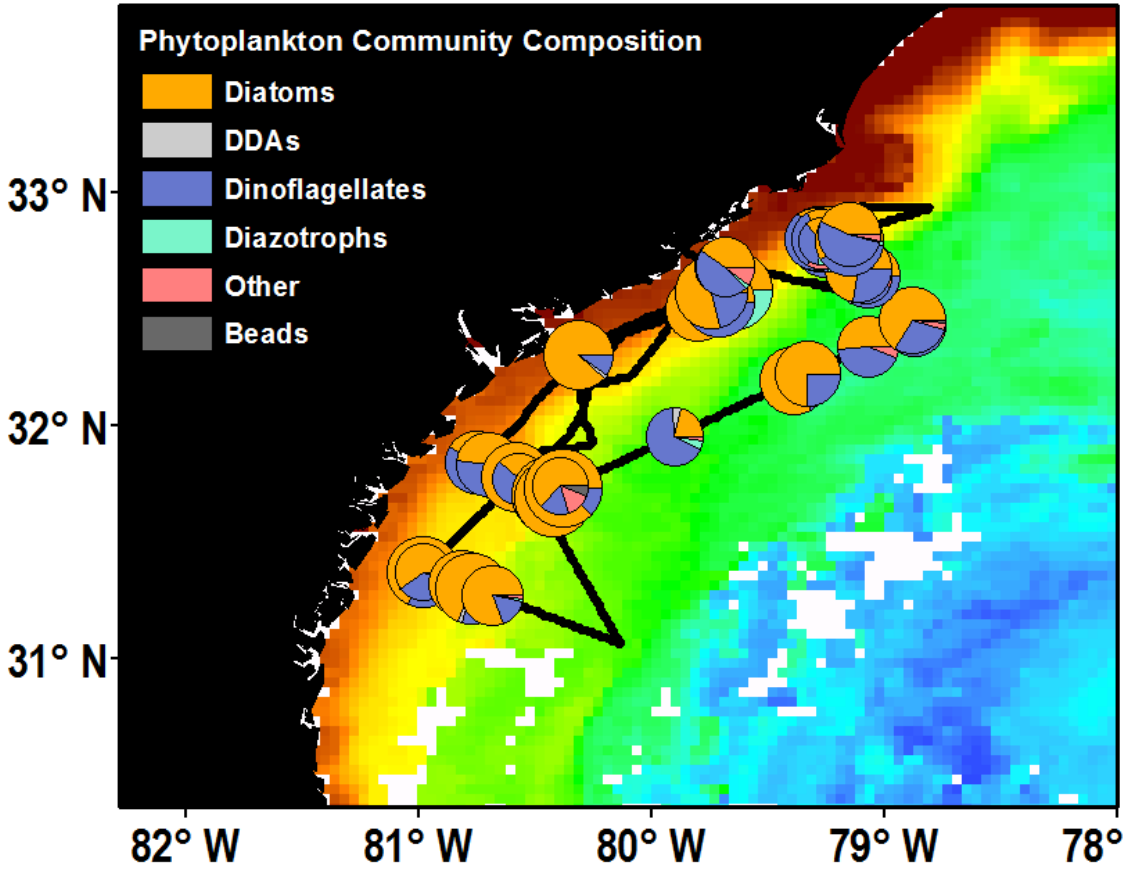


Variability of phytoplankton specific absorption coefficient (Oct. 2016)

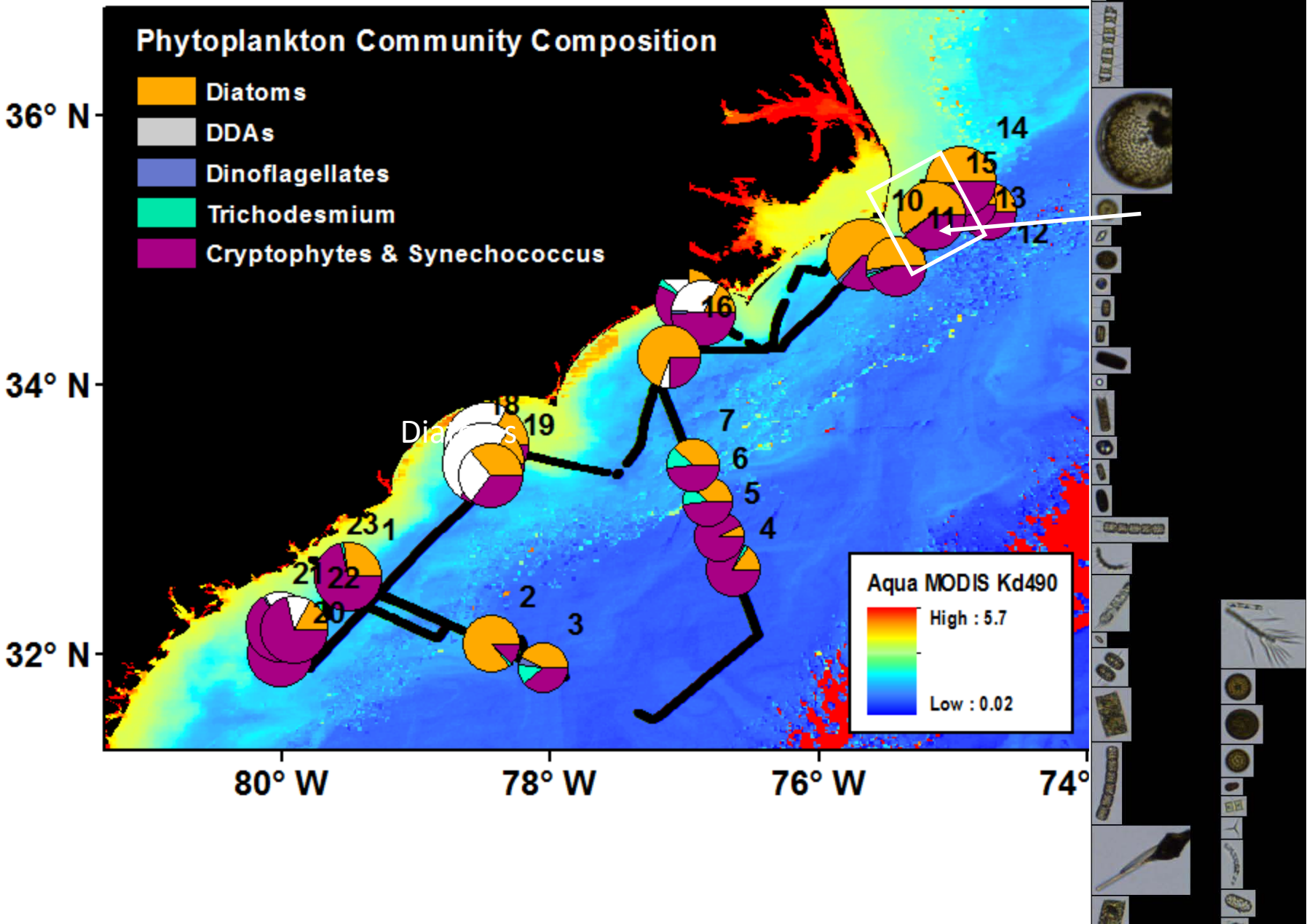


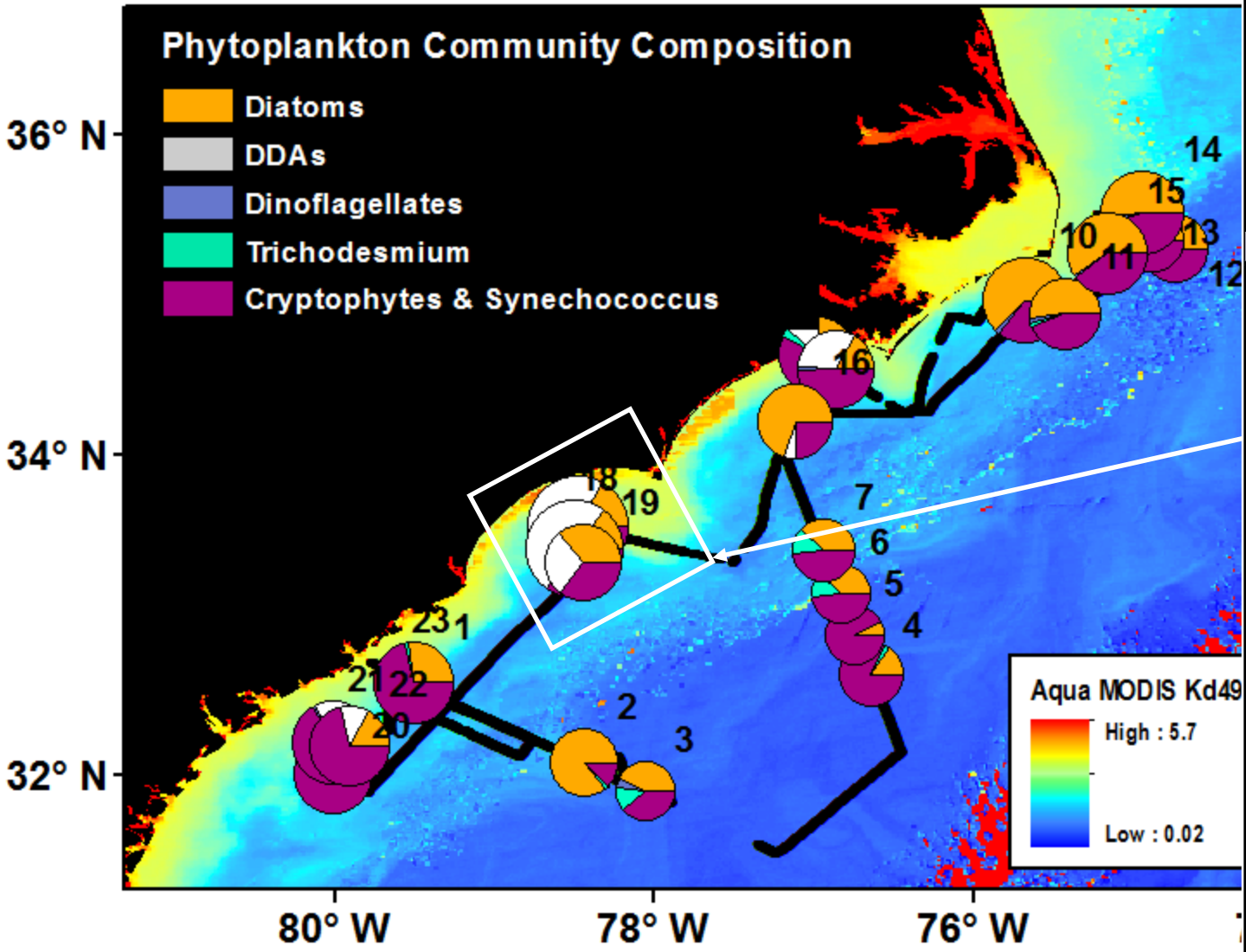
Diversity of PFTs during cruise 2016

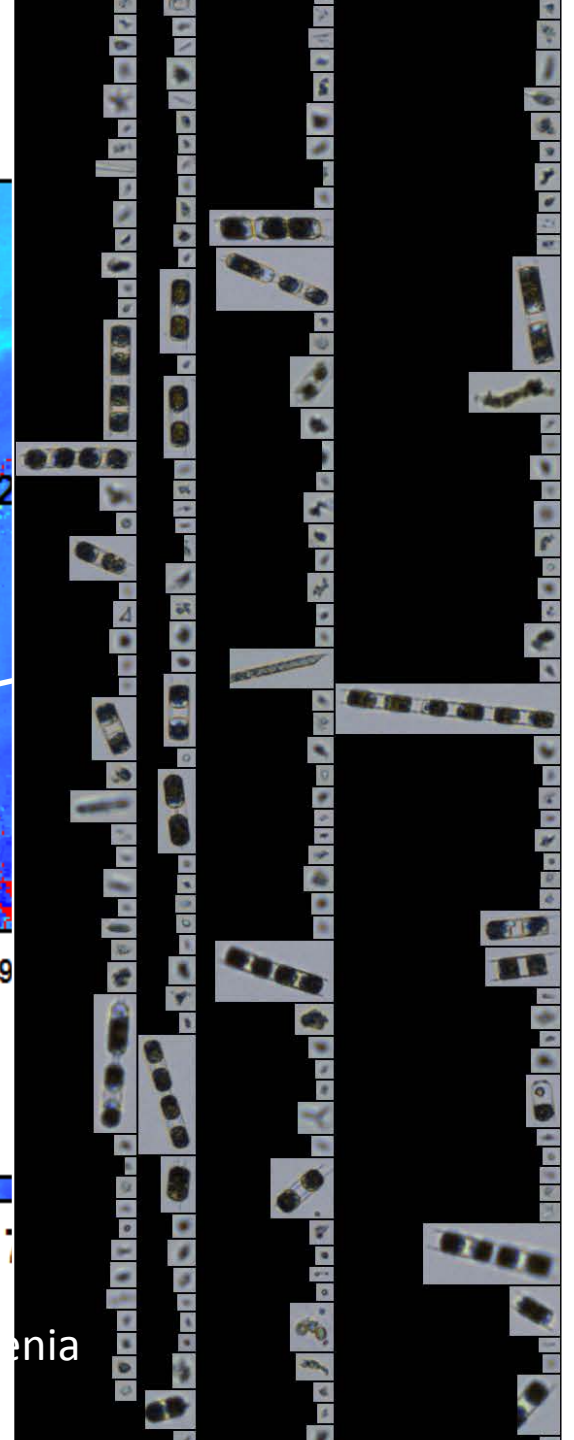




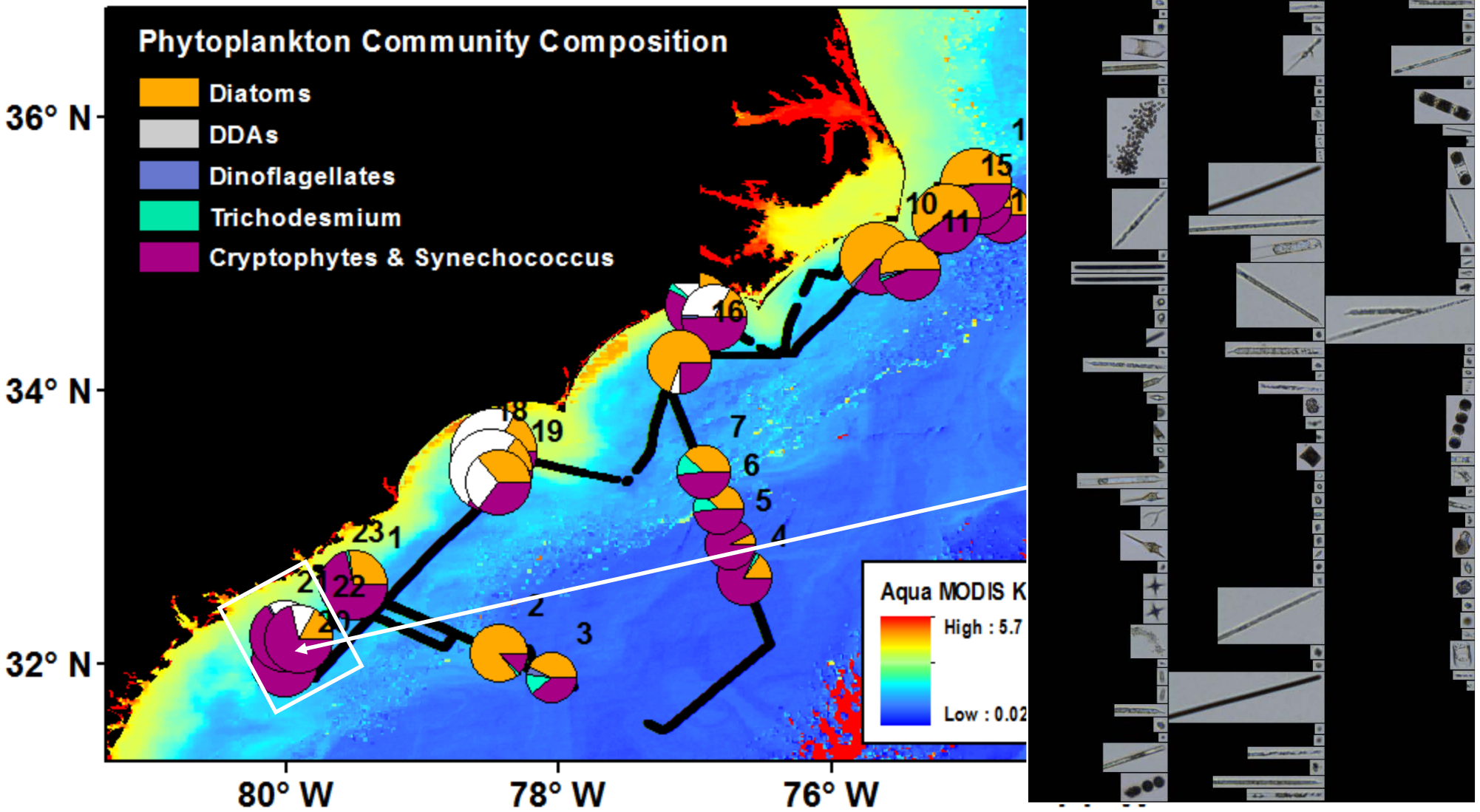
Distribution of major PFTs during 2014 and 2016 cruises


Phytoplankton Community Composition
Diatoms
DDAs
Dinoflagellates
Trichodesmium
Cryptophytes & Synechococcus
36° N
34° N
32° N
80° W
78° W
76° W
74°
Aqua MODIS Kd490
High : 5.7
Low : 0.02
1
2
3
4
5
6
7
10
11
12
13
14
15
16
18
19
20
21
22
23


Phytoplankton Community Composition
Diatoms
DDAs
Dinoflagellates
Trichodesmium
Cryptophytes & Synechococcus
36° N
34° N
32° N
80° W
78° W
76° W
Aqua MODIS Kd49
High : 5.7
Low : 0.02
1
2
3
4
5
6
7
10
11
12
13
14
15
16
18
19
20
21
22
23



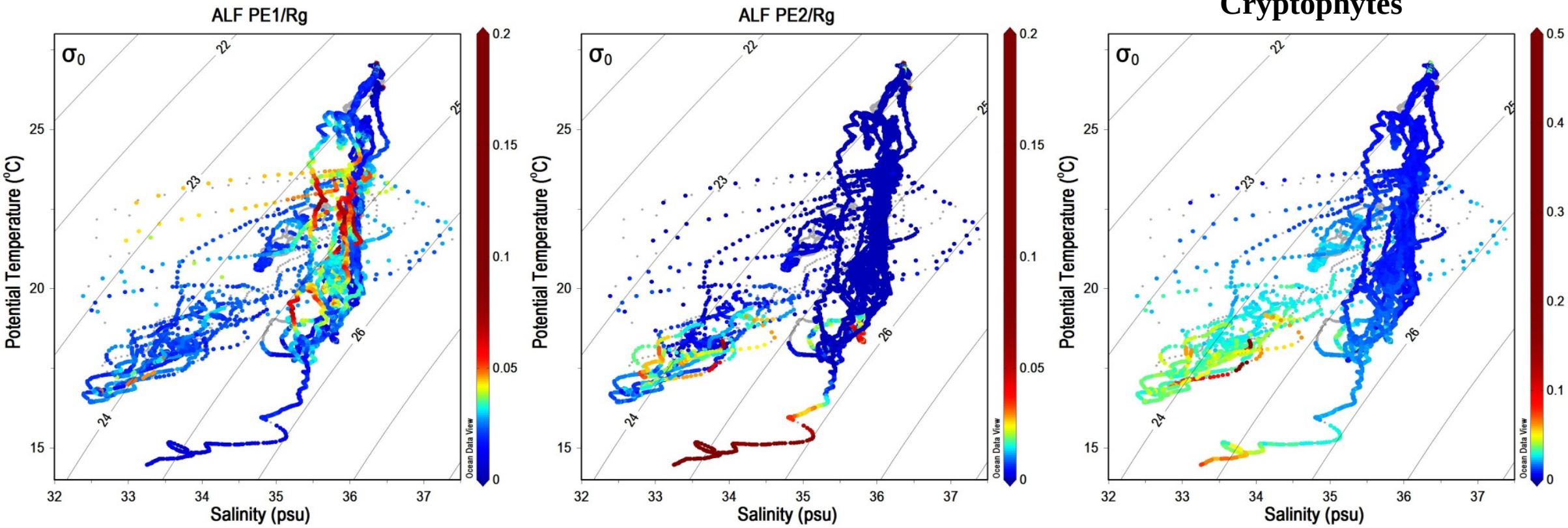
enia


Phytoplankton Community Composition
Diatoms
DDAs
Dinoflagellates
Trichodesmium
Cryptophytes & Synechococcus
36° N
34° N
32° N
80° W
78° W
76° W
Aqua MODIS K
High : 5.7
Low : 0.02

Blue water cyanobacteria

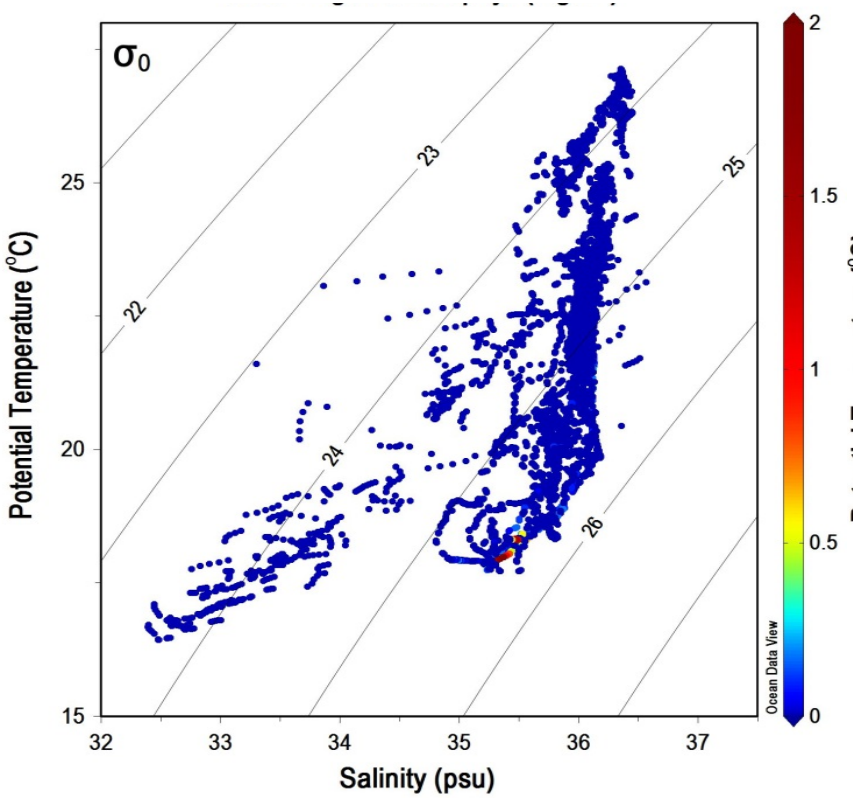
Coastal water cyanobacteria

Cryptophytes

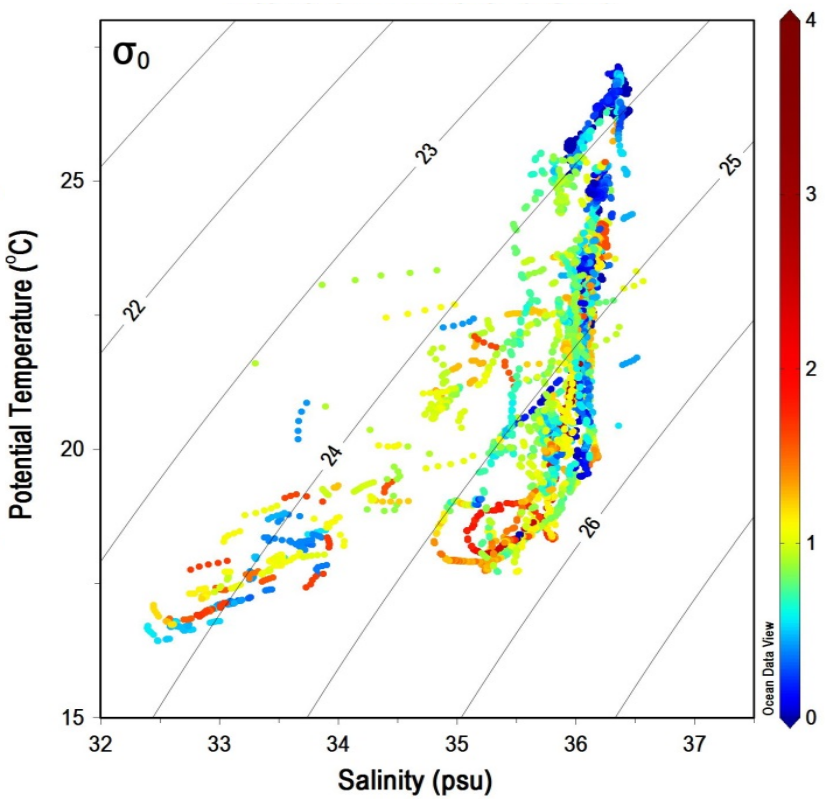


T-S plots showing PFTs associated with different water types

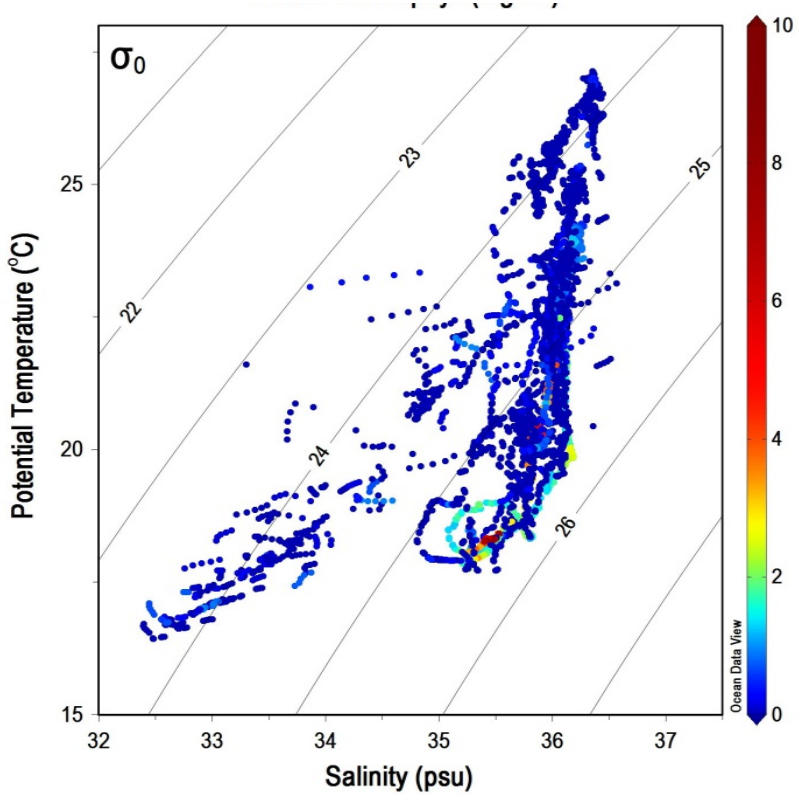
Green Algae



Cryptophytes



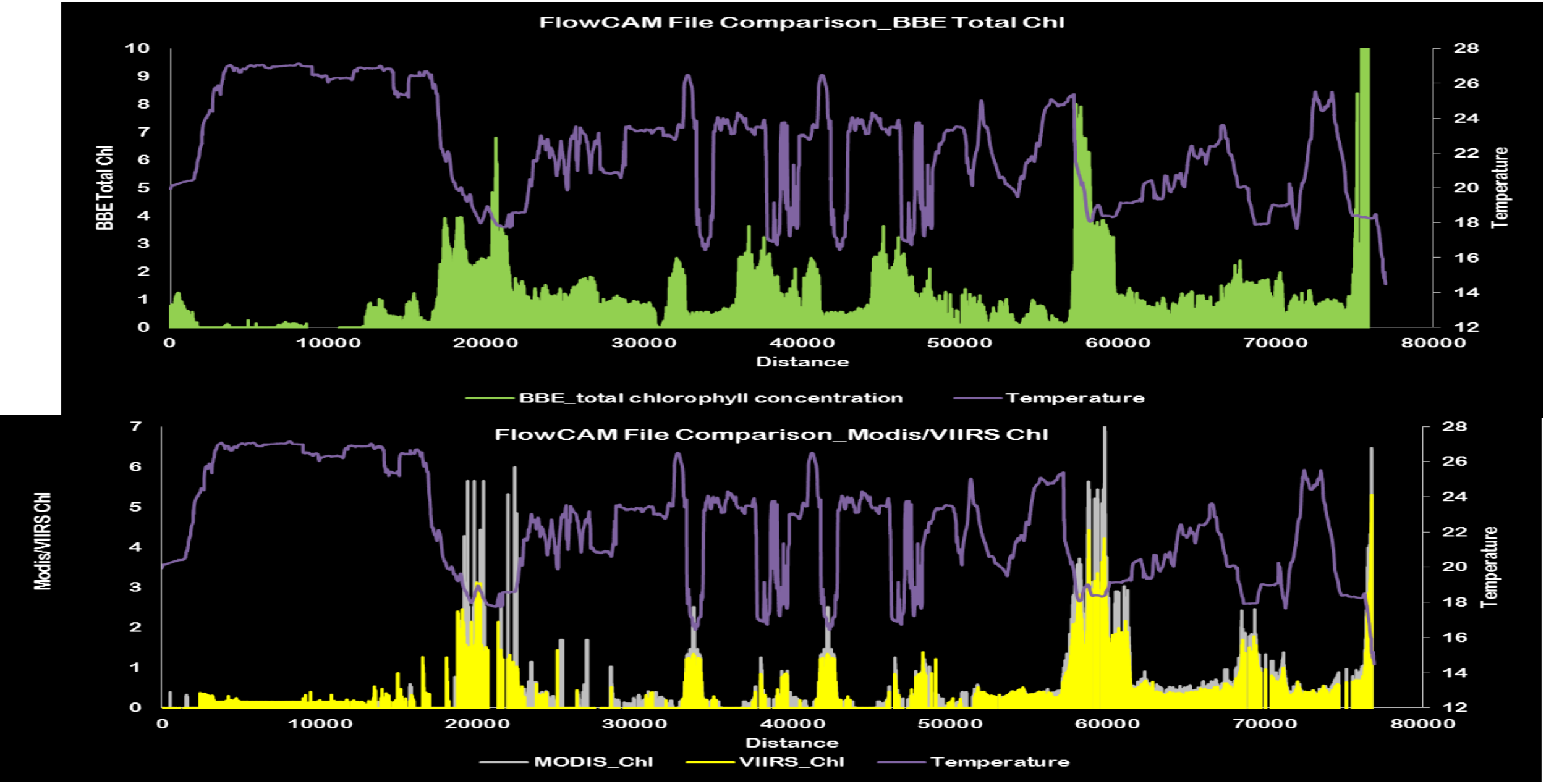
Diatoms



T-S plots showing PFTs associated with different water types

NANCY FOSTER CRUISE - 2014

Jenkins, Christy A., Joaquim I. Goes, Kali McKee, Helga D. R. Gomes, Robert Arnone, Menghua Wang, Michael Ondrusek et al. (2016) High-resolution shipboard measurements of phytoplankton: a way forward for enhancing the utility of satellite SST and chlorophyll for mapping microscale features and frontal zones in coastal waters." In *SPIE Asia-Pacific Remote Sensing*, pp. 98780U-98780U. International Society for Optics and Photonics, 2016.

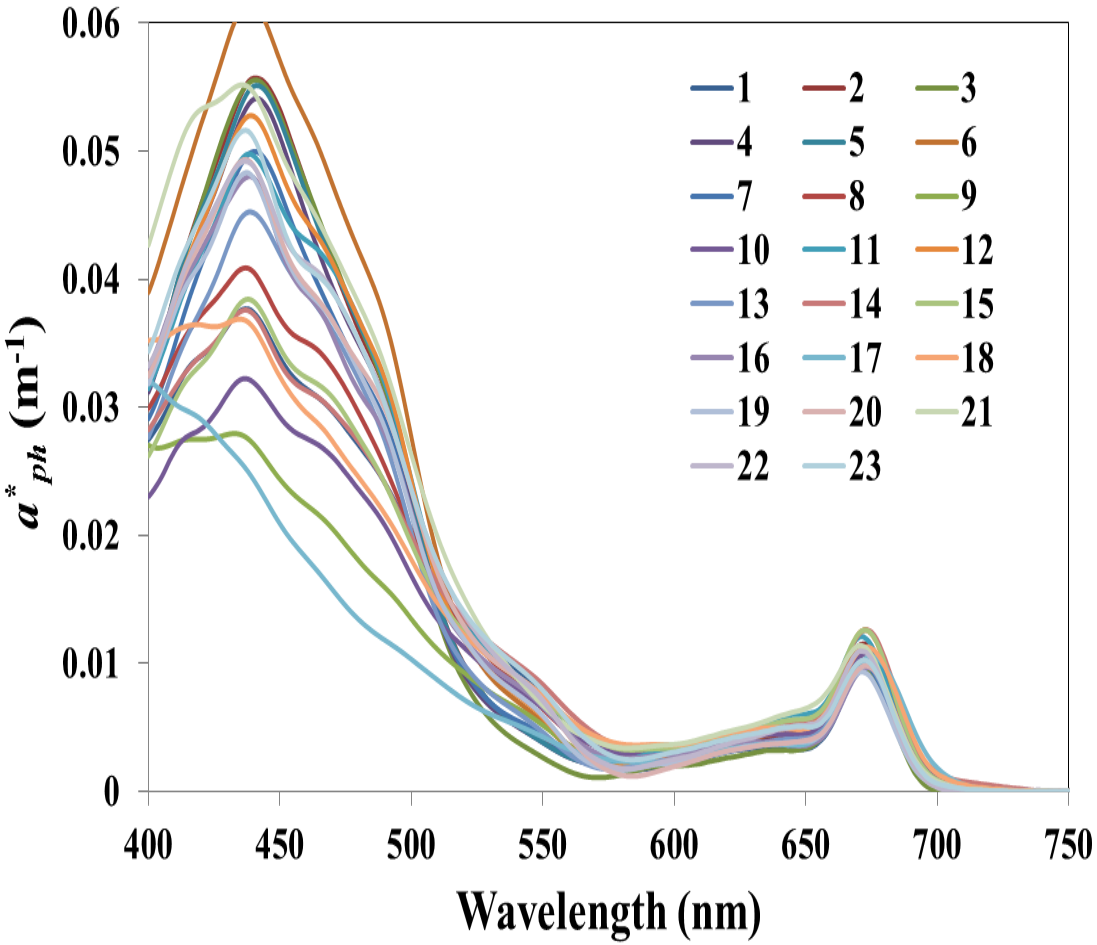

FlowCAM File Comparison_BBE Total Chl
BBE Total Chl
Temperature
Distance
BBE_total chlorophyll concentration
Temperature
FlowCAM File Comparison_Modis/VIIRS Chl
Modis/VIIRS Chl
Temperature
Distance
MODIS_Chl
VIIRS_Chl
Temperature

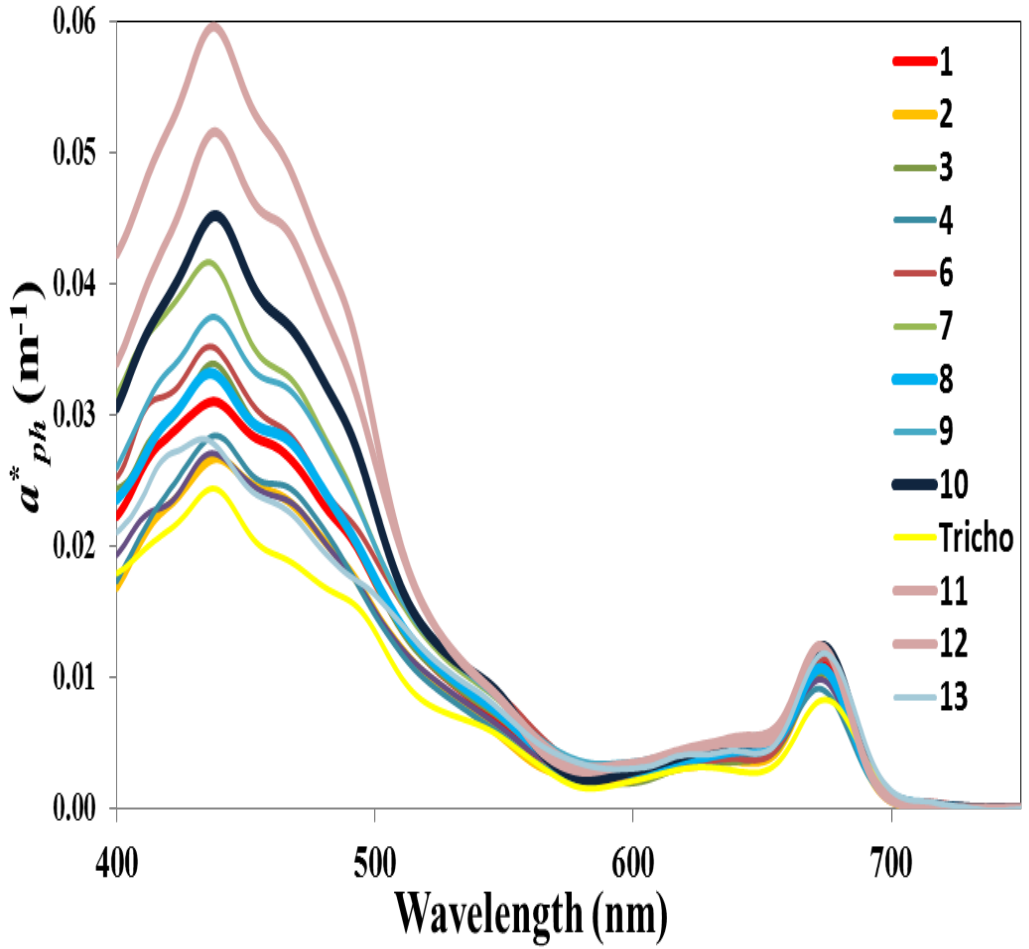
FUTURE PLANS

- Distribution patterns of PFTs in relation to microscale features and frontal zones
- Estimation of net primary productivity using measurements of phytoplankton absorption cross section and quantum yield

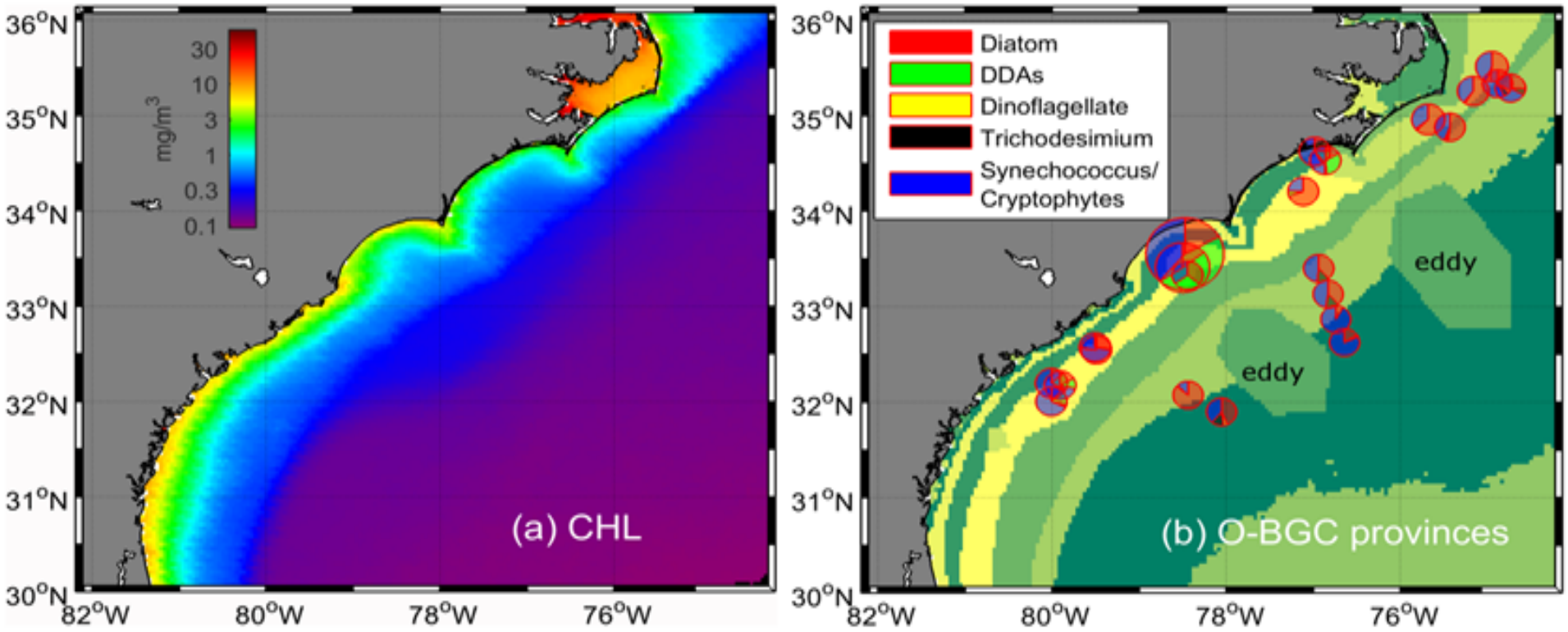
$$\mathbf{NPP\ (z) = \int \phi\ (z) \times a_{ph} \times E(z, \lambda)\ d\lambda}$$

- Validation with deck incubation based measurements of net primary productivity
- Utilize O-BGC provinces of Wei-Lee (2016) for scaling shipboard measurements to regional, basin and global scales
- Compare with sea surface nitrate and new production measurements from NPP-VIIRS

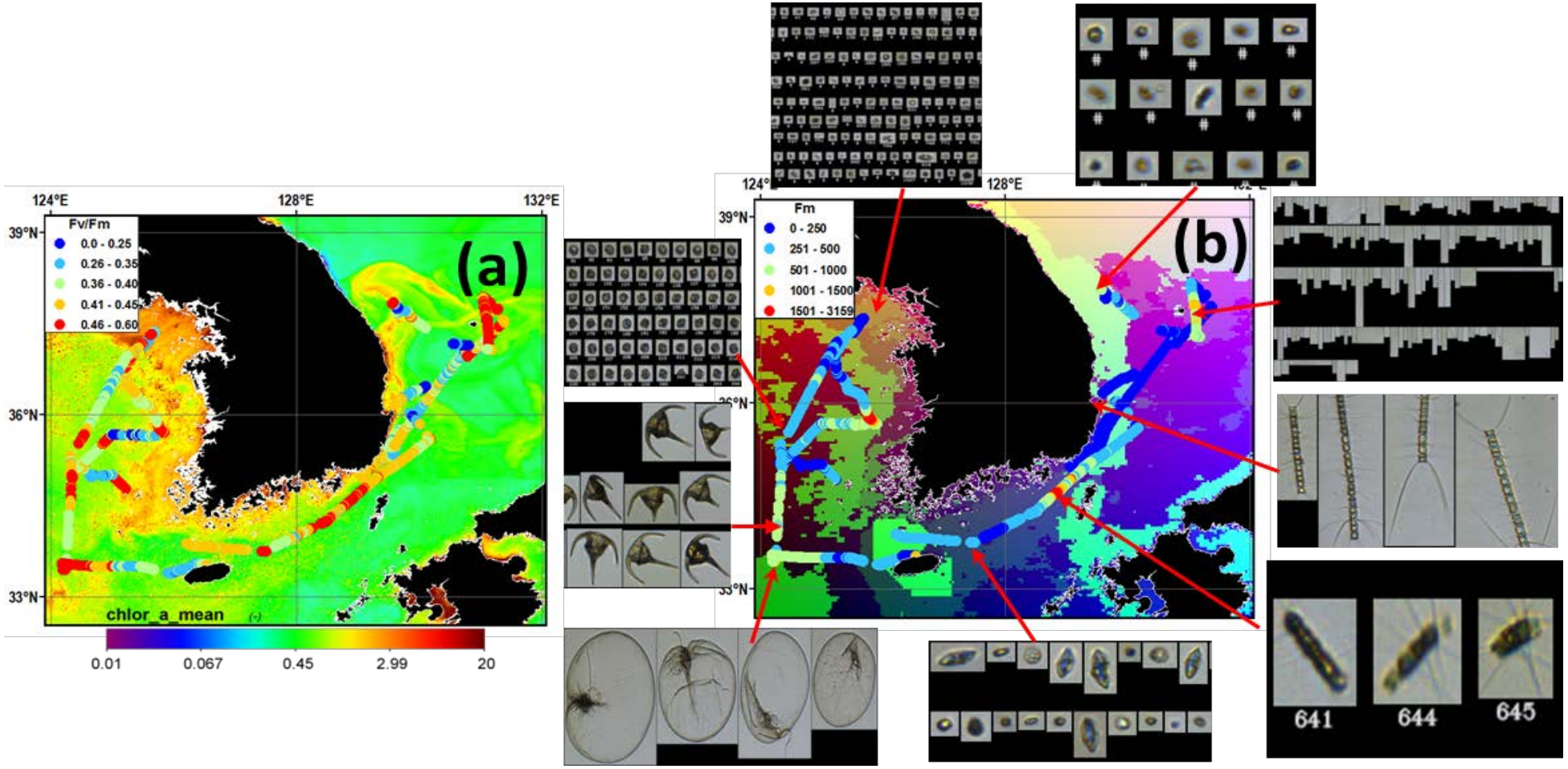




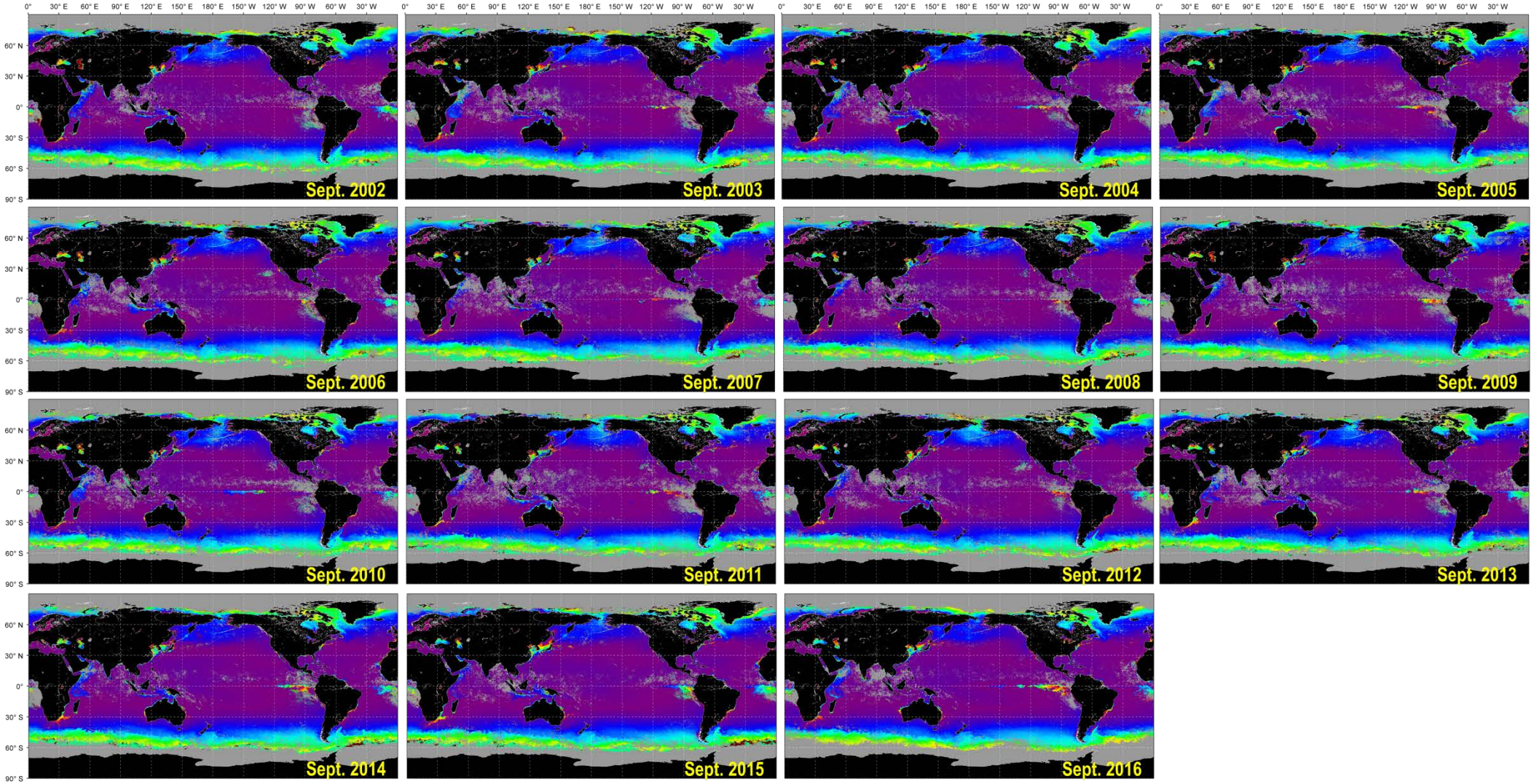
Comparison of phytoplankton specific absorption coefficient during cruises of 2014 and 2016



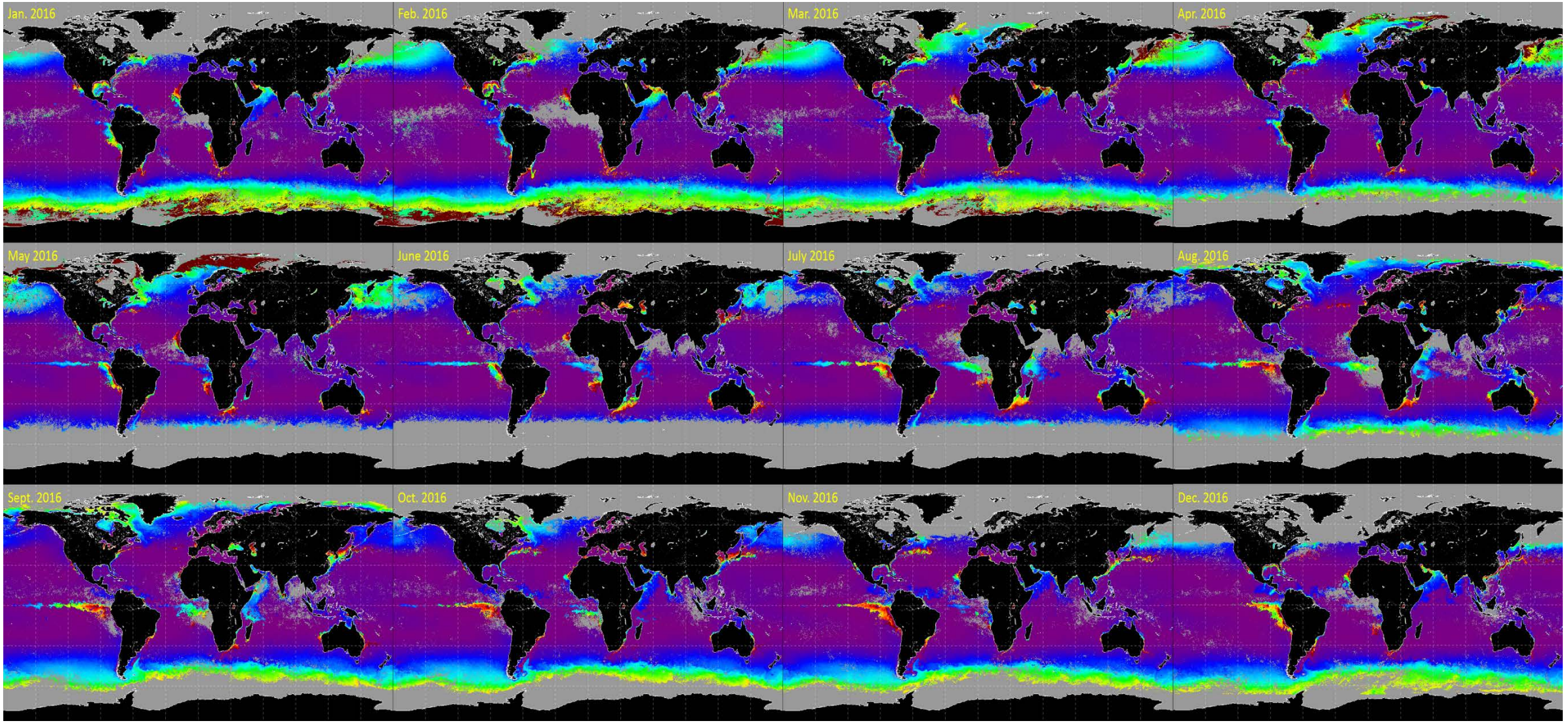
a*) Chl* distributionsouthwest of Sargasso Sea (November 2014); (b) O-BGC provinces derived for the cruise area, with each province denoted by different colors. Two eddies associated with the Gulf Stream are visible in the new O-BGC provinces. Overlaid pie charts denote the percentages of PFTs and the total cell abundance showing differences in PFTs and cell numbers with each province.



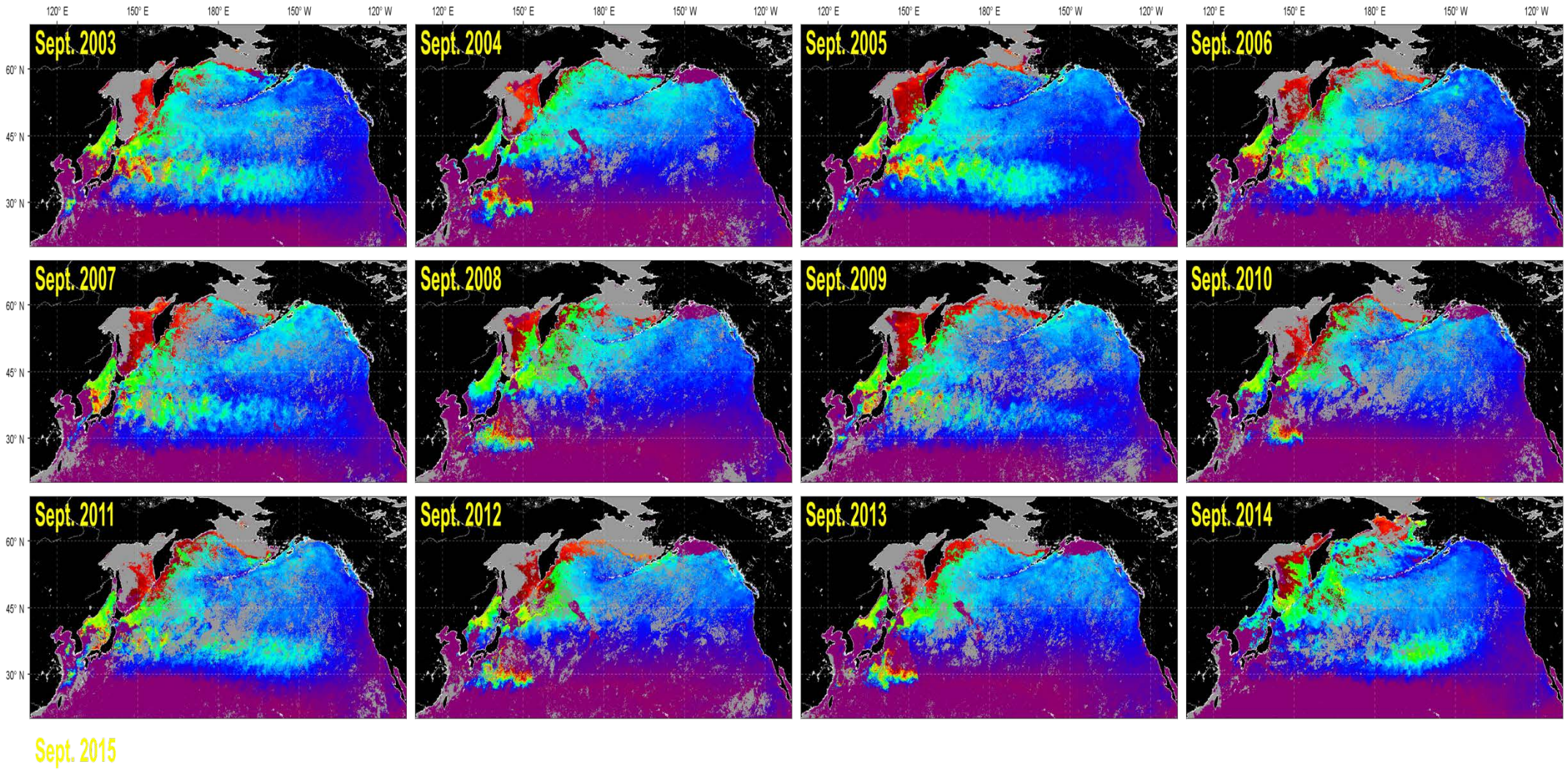
NASA-KORUS Cruise Track (May-June 2016) and variable fluorescence (F_v/F_m) values shown in inset super-imposed on Aqua-MODIS *Chl* for waters around Korean Peninsula, (b) O-BGC provinces (May-2016) derived using Wei et al (2016) approach with each province denoted by different colors. Superimposed on O-BGC provinces are fluorescence values showing high/low phytoplankton biomass areas indicated by higher/lower fluorescence. Also shown PFTs associated with O-BGC province



Interannual variability in sea surface nitrate for Sept. from MODIS-Aqua



Monthly maps of sea surface nitrate showing changes in nitrate inputs and drawdown



Interannual variation in nitrate based new production measurements in the North Pacific Ocean from MODIS-Aqua

THANK YOU


NOAA NESDIS STAR
Weather and Water
SMC
CORP
Climate
Ecosystems
SOC
Commerce
Center for Satellite Applications and Research

NOAA/NESDIS Technical Reports on Dedicated VIIRS Cal/Val Cruises

Veronica P. Lance*
and VIIRS Cal/Val Cruise Team Members
*Global Science & Technology, Inc.



NOAA Ship *Nancy Foster*
2014, 2015, and 2016



NOAA Ship *Okeanos Explorer* –
April/May 2018

2016 STAR/JPSS Annual Science Meeting
College Park, MD, 14-18 August 2017

Acknowledgements

- NOAA/JPSS Ocean Color Cal/Val team
- Officers and crew of the NOAA Ship *Nancy Foster*
- NOAA OMAO
- NOAA JPSS program
- NOAA STAR Ocean Color EDR team
- NOAA CoastWatch/OceanWatch Central

VIIRS Cal/Val Cruises

Outline

•NOAA dedicated to VIIRS Cal/Val cruises (Annual each fiscal year):

- •Participating groups
- •Objectives
- •Observations
- •Reports Published
  - •2014 (NF-14-09) – NESDIS #146 http://dx.doi.org/10.7289/V52B8W0Z
  - •2015 (NF-15-13) – NESDIS #148 http://doi.org/10.7289/V5/TR-NESDIS-148
- •Report currently in progress for 2016 (NF-16-08)
- •Future: April/May 2018 – TBD
- •Data submission and archiving status and next steps

VIIRS Cal/Val Cruises

Participating Institutions

US Agencies:

NOAA/STAR
NASA/GSFC (2014, 2015)
National Institute of Standards and Technology (NIST)
Naval Research Lab (Stennis)

Universities:

U. Southern Mississippi
U. Miami
U. South Florida
U. Massachusetts – Boston
City College of NY
LDEO at Columbia
HBOI at Florida Atlantic U. (2016)

International:

Joint Research Centre of the European Commission (2014)

VIIRS Cal/Val Cruises

Cruise Objectives:

1) *Validate VIIRS ocean color satellite remote sensing*

2) *Characterize and quantify sources of uncertainty associated with in situ ocean color measurements*

3) *Characterize the optical properties of dynamic ocean processes*

VIIRS Cal/Val Cruises

Representative Measurements

In water profiling, surface floating and above water ocean radiometry



Apparent Optical Properties (AOPs) – Remote sensing reflectance - Simultaneous profiles with several instruments (e.g. HyperPro; MicroPro (2014 only); C-OPS; also several handheld and deck-mounted instruments)

VIIRS Cal/Val Cruises

Representative Measurements

In water profiling, surface floating and above water ocean radiometry



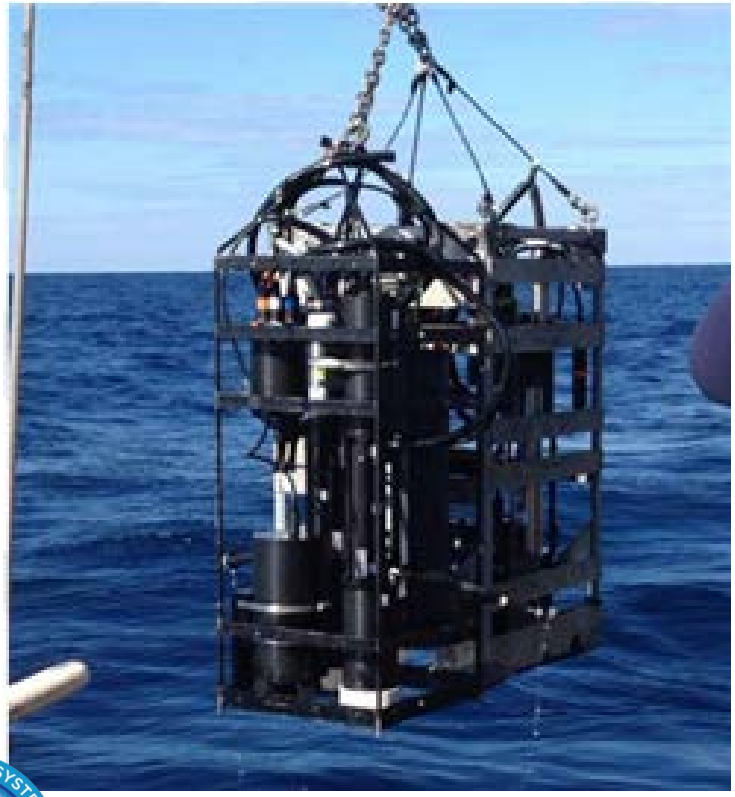




VIIRS Cal/Val Cruises

Representative Measurements

In water profiling, surface floating and above water ocean radiometry



Inherent Optical Properties (IOPs) -Total absorption; CDOM absorption; scatter and backscatter; fluorometry (chlorophyll, CDOM, phycoerythrin)

VIIRS Cal/Val Cruises

Representative Measurements

Flow-through continuous measurements

- **IOPs -** Beam attenuation/scattering; backscatter; CDOM and chlorophyll fluorescence
- **Phytoplankton characterization** - Dynamic imaging particle analysis (FlowCam); phytoplankton functional groups; chlorophyll and phycobilipigments; photosynthetic efficiency



VIIRS Cal/Val Cruises

Representative Measurements

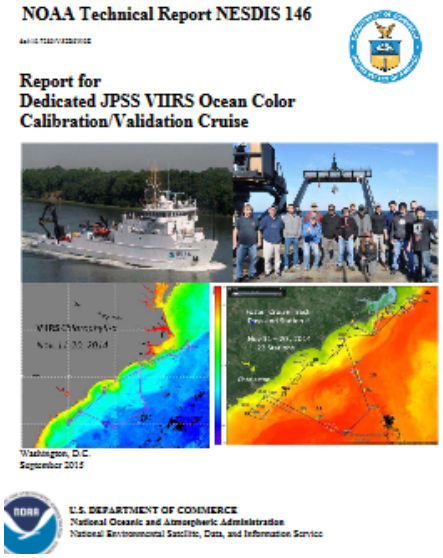
Discrete water sampling and analyses

Filter pad spectral absorption
HPLC phytoplankton pigment analyses
CDOM absorption
Dissolved organic carbon
Particulate organic carbon and particulate nitrogen
Fluorometric extracted chlorophyll
Suspended particulate material
Particle fluorescence and digital imaging (FlowCam)
Variable fluorescence (2014 only)
Advanced Laser Fluorometer (ALF; 2014 only)
Phycobilipigment concentration (2014 only)

VIIRS Cal/Val Cruises

NESDIS Technical Reports

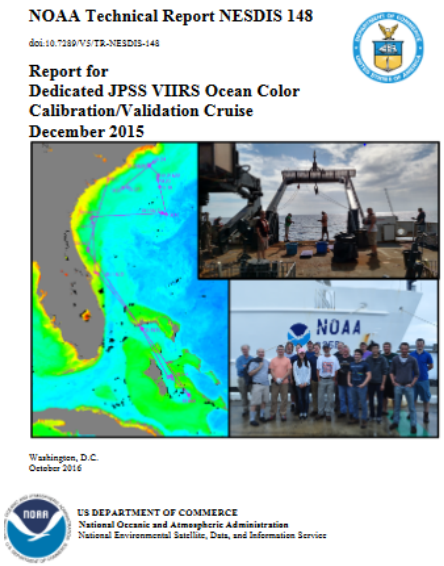
- NOAA dedicated to VIIRS Cal/Val cruises (Annual each fiscal year):
  - Completed
    - **2014** (NF-14-09) – NESDIS #146 published http://dx.doi.org/10.7289/V52B8W0Z
    - **2015** (NF-15-13) – NESDIS #148 published http://doi.org/10.7289/V5/TR-NESDIS-148
  - In Progress
    - **2016** (NF-16-08) – Report *in progress*
    - Draft of content and Tables A1-A7 sent out last week
    - Please discuss at workshop tomorrow:
      - proposed "Above Water Group" chapter
      - Review Tables A1-A7
    - Next draft before Labor Day


NOAA Technical Report NESDIS 146

Report for
Dedicated JPSS VIIRS Ocean Color
Calibration/Validation Cruise

Washington, D.C.
September 2015

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


NOAA Technical Report NESDIS 148

doi.10.7289/V5/TR-NESDIS-148

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

Washington, D.C.
October 2016

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

VIIRS Cal/Val Cruises

Next Cruise

April/May 2018

Depart: Florida Keys

Return:



NOAA Ship *Okeanos Explorer*

VIIRS Cal/Val Cruises

Data Submission and Archiving

- **Dr. Sheekela Baker-Yeboah,** Physical Oceanographer from NCEI has joined STAR/SOCD and will be working on in situ archiving.
- **2014 (NF-14-09) Data–** Initiated archive with NCEI with data on hand. Ascension number and DOI are TBD. Please submit outstanding datasets.
- **2015 (NF-15-13) and 2016 (NF-16-08) Data–** Assembling datasets now – please submit your data.
- Data Submission Log on Google Drive: https://docs.google.com/spreadsheets/d/1p2zbFR0pVrxknHOkoE8EC5yDfTh9sfscpcsxyx9IOH8/edit#gid=1730912765

VIIRS Cal/Val Etc.

Summary

- 3 Successful dedicated cruises:
  - 2014 http://dx.doi.org/10.7289/V52B8W0Z
  - 2015 http://doi.org/10.7289/V5/TR-NESDIS-148
  - 2016 Report *In progress*
- Next cruise, NOAA Ship *Okeanus Explorer,* April/May 2018
- Message for participants:
  - Please submit outstanding datasets for 2014, 2015 and 2016
  - Please work with Sheekela for preparing or updating your datasets for archiving

VIIRS Cal/Val Cruises

Data Submission Log pages to follow

- Data Submission Log on Google Drive: https://docs.google.com/spreadsheets/d/1p2zbFR0pVrxknHOkoE8EC5yDfTh9sfscpcsxyx9IOH8/edit#gid=1730912765

VIIRS Cal/Val Cruises

2014
Pg 1 of 3

Accounting of Cruise Data Submissions NF-14-09				
Group	Dataset	Status (VL)	Mike O. has?	Menghua has?
NOAA/STAR (Mike)	Hyperpro profiling (Rrs, etc.)	only matchup stations (n=9)	yes	yes
NOAA/STAR (Mike)	ECO Pucks on Hyperpro 2x triplets (Chl, CDOM, phycoerythrin, bb at 443, 450 860)		no - reprocessing required; not highest priority; completion date expected: TBD	
NOAA/STAR (Mike)	chl-a fluorometric (method?)		yes	
NOAA/STAR (Mike)	Microtops	https://aeronet.gsfc.nasa.gov/new_web/cruises_new/Nancy_Foster_14.html	online	
NOAA/STAR (Mike)	ASD (Rrs - above water)		yes	
~~NOAA/STAR (Eric)~~	~~TSM~~	not available, samples melted	n/a data not available	n/a
Stennis (Ryan - USM)	ASD (Rrs - above water)	only matchup stations (n=9 this might be everything for handheld)	yes; Mike says 9 stations is complete	yes
Stennis (NRL)	ASD (Rrs - above water)			
Stennis (Ryan)	Hyperpro (Rrs - floating)	only matchup stations (n=9; check on whether more stations for floating)	yes; Mike says 9 stations is complete	yes
Stennis (Bob)	Flowthrough ac9 unfiltered (a, b, c)	x	yes	yes
Stennis (Bob)	Flowthrough ac9 filtered (ag, ap,	x	yes	yes
Stennis (Bob)	Flowthrough (bb)	x	yes	yes
Stennis (?)	Microtops	available online?	Not found at aeronet site?	

VIIRS Cal/Val Cruises

2014
Pg 2 of 3

Accounting of Cruise Data Submissions NF-14-09				
Group	Dataset	Status (VL)	Mike O. has?	Menghua has?
UMB (Jianwei)	SBA floating hyperpro (Rrs)	x	yes	yes
UMB (Jianwei)	IOP BB9 (bb)	x	yes	yes
UMB (Jianwei)	IOP ACS180 filtered and unfiltered (apg, cpg)	x	yes	yes
~~UMB (Junfang)~~	~~Spectral Evolution Handheld~~	not available because of incorrect setup.	n/a data not available	
USF (David)	Filter Pad Absorption (ap, ad, aph)	x	yes	yes
USF (David)	Chlorophyll (Welschmeyer)	x	yes	yes
USF (David)	Chlorophyll (Acidification)	x	yes	
USF (David)	ASD HandHeld above water (Rrs)	7 stations - (this is probably everything they have?)	yes; Mike says 7 stations is complete	yes
USF (?)	Microtops	available online?	Not found at aeronet site?	
USF (?)	Hyperpro		yes	yes
CCNY	Hypersas-POL		yes	
CCNY	GER		yes	
CCNY	Microtops	available online?	Not found at aeronet site?	
JRC (Giuseppe)	Micropro (profiling; Es, Ed, Lu, Kl?, Kd, Eu, Ku, R, Q, Rrs nLw	x	yes	yes
JRC (Giuseppe)	IOPs in same file, maybe calculated??	x	yes	yes
JRC (Giuseppe)	TRIoS- he says most data no good - good at 5 stations)	x	yes; 5 stations	yes

VIIRS Cal/Val Cruises

2014
Pg 3 of 3

Accounting of Cruise Data Submissions NF-14-09				
Group	Dataset	Status (VL)	Mike O. has?	Menghua has?
NASA(Scott)	C-OPS (profilling Rrs: Ed, Lu, Es,	x	yes	yes
NASA(Scott)	IOPS (acs, unfiltered: cgp, agp, ag,)	x	yes	yes
NASA(Scott)	IOPS (ac9, filtered: ag)	x	yes	yes
NASA(Scott)	IOPS (bb3: bbp)	x	yes	yes
NASA(Scott)	IOPS (VSF-9: VSF)	x	yes	yes
NASA(Scott)	HyperSAS		no	
NASA (Aimee)	POC	x	yes - pulled from NASA SeaBASS	
NASA (Aimee)	DOC	x	yes - pulled from NASA SeaBASS	
NASA (Aimee)	CDOM	x	yes - pulled from NASA SeaBASS	
NASA (Aimee/Crystal)	HPLC	x	yes	yes
LDEO (Joaquim)	ALF		no	
LDEO (Joaquim)	FIRe		no	
LDEO (Joaquim)	bbe		no	
LDEO (Joaquim)	phyocobilipigments		no	
LDEO (Joaquim)	Flow Cam		no	
LDEO (Joaquim)	microscopy		no	
U. Miami (Ken)	NURADS (8 stations)	X	y	
NIST	n/a		n/a	n/a

VIIRS Cal/Val Cruises

2015
Pg 1 of 3

Accounting of Cruise Data Submissions NF-15-13				
Group		Dec-15	Mike O. has?	Menghua has?
NOAA/STAR (Mike)	Hyperpro profiling (Rrs)	x only values for VIIRS matchups	yes	yes
NOAA/STAR (Mike)	ECO Pucks on Hyperpro 2x triplets (Chl, CDOM, phycoerythrin, bb at 443, 450 860)		no - reprocessing required; not highest priority; completion date expected: TBD	
NOAA/STAR (Mike)	chl-a fluorometric (Welschmeyer)		yes	
NOAA/STAR (Mike)	ASD (Rrs - above water)	check for completeness	MO checking	
NOAA/STAR (Eric)	TSM		yes	
Stennis (Ryan - USM)	ASD (Rrs - above water)	check for completeness	MO checking	
Stennis (NRL)	ASD (Rrs - above water)	check for completeness	MO checking	
Stennis (Ryan)	Hyperpro (Rrs - floating)		yes - has 2 sets; USM (Ryan) and NRL (Wesley); both processed by Sherwin	no - only station info. For Floating Hyperpros
Stennis (Bob)	Flowthrough ac9 unfiltered (a, b, c)		no	
Stennis (Bob)	Flowthrough ac9 filtered (ag, ap,		no	
Stennis (Bob)	Flowthrough (bb)		no	
UMB (Jianwei)	RISBA (was SBA) floating hyperpro (Rrs)		yes	no - only station info.
UMB (Jianwei)	IOP BB7FL2 (bb at 412, 440, 488, 532, 595, 695, 715; CDOM fl; Chl fl)		no	
UMB (Jianwei)	IOP ACS180 filtered and unfiltered (apg, cpg)		no	
UMB (Guoqing)	Flow Cytobot		no	
UMB (Junfang)	Spectral Evolution Handheld	check for completeness	MO checking	

VIIRS Cal/Val Cruises

2015
Pg 2 of 3

Accounting of Cruise Data Submissions NF-15-13				
Group		Dec-15	Mike O. has?	Menghua has?
USF (David)	Filter Pad Absorption (ap, ad, aph)	x (rec'd but trouble unzipping)	MO checking	
USF (David)	Chlorophyll (Welschmeyer)	x (rec'd but trouble unzipping)	yes	yes
USF (David)	Chlorophyll (Acidification)	x (rec'd but trouble unzipping)	yes	yes
USF (David)	CDOM absorption (new for 2015 from ap sampling)	x (rec'd but trouble unzipping)	MO checking	
USF (David)	ASD HandHeld above water (Rrs)	check for completeness	MO checking	
USF	Microtops	https://aeronet.gsfc.nasa.gov/new_web/cruises_new/Nancy_Foster_15.html	n/a	
USF (?)	Hyperpro - profiling	x (rec'd but trouble unzipping)	yes - Mike has good files	yes
CCNY	Hypersas-POL	only for matchup stations; only at VIIRS channels	yes; MO has all	no - only 3 photos
CCNY	ASD	only for matchup stations; only at VIIRS channels	MO checking	
CCNY	GER	only for matchup stations; only at VIIRS channels	yes; MO has all	
OSU (Nick)	Hyperpro - profiling		yes	yes, but all directories (need to arrange for matchup)
OSU (Nick)	Spectral Evolution Handheld	check for completeness	MO checking	

VIIRS Cal/Val Cruises

2015
Pg 3 of 3

Accounting of Cruise Data Submissions NF-15-13				
Group		Dec-15	Mike O. has?	Menghua has?
NASA(Scott)	C-OPS (profilling Rrs: Ed, Lu, Es,		no	
NASA(Scott)	C-OPS (profilling Rrs: Ed, Lu, Es,		no	
NASA(Scott)	IOPS (acs, unfiltered: cgp, agp, ag,)		no	
NASA(Scott)	IOPS (ac9, filtered: ag)		no	
NASA(Scott)	IOPS (bb3: bbp)		no	
NASA(Scott)	IOPS (VSF-9: VSF)		no	
NASA(Scott)	HyperSAS		no	
NASA (Joaquin C.)	POC		yes - pulled from NASA SeaBASS	
NASA (Joaquin C.)	DOC		yes - pulled from NASA SeaBASS	
NASA (Joaquin C.)	CDOM		yes - pulled from NASA SeaBASS	
NASA (Joaquin C.)	HPLC	X	yes	yes
LDEO (Joaquim G.)	Nutrients (which?)		no	
LDEO (Joaquim G.)	Flow Cam		no	
U. Miami (Ken)	NURADS (8 stations)	X	yes	

VIIRS Cal/Val Cruises

2016
Pg 1 of 2

Accounting of Cruise Data Submissions NF-16-08				
Group		Oct-16	Mike O. has?	Menghua has?
NOAA/STAR (Mike)	Hyperpro profiling (Rrs)		yes	yes (SeungHyun confirm?)
NOAA/STAR (Mike)	ASD	Rrs		
NOAA/STAR (Mike)	operated NASA C-OPS	nlw, Rrs		
NOAA/STAR (Mike)	water samples to be analyzed by NASA	HPLC, POC, DOC, CDOM		
NOAA/STAR (Eric)	SPM (TSS)	SPM		
USF	Microtops	https://aeronet.gsfc.nasa.gov/new_web/cruises_new/Nancy_Foster_16.html		
USF	Extracted Chl-a	Chl-a		
USF	Filter Pad Absorption	a, ad, ag		
CCNY_Gilerson	HyperSAS	RRS for stations only (no underway)		
CCNY_Gilerson	GER	RRS for stations		
LDEO_Goes	Nutrients	N02+N03, Si, P		
LDEO_Goes	Phycobilipigments	concentrations		
LDEO_Goes	microscopy	phtyoplankton counts, ID		
LDEO_Goes	FIRe	fv/fm, sigma		
LDEO_Goes	ALF	several		
LDEO_Goes	FlowCAM	phptyoplankton types		

VIIRS Cal/Val Cruises

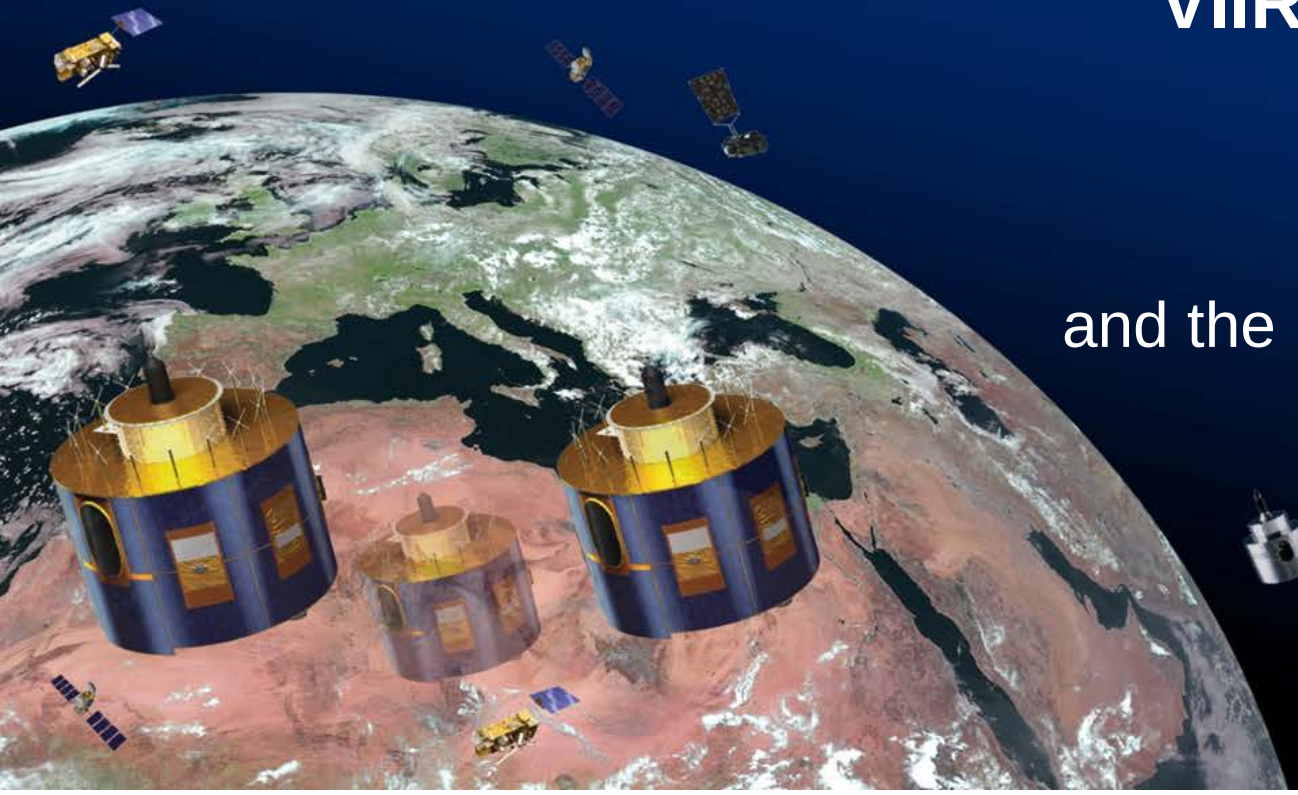
2016
Pg 2 of 2

Accounting of Cruise Data Submissions NF-16-08				
Group		Oct-16	Mike O. has?	Menghua has?
UMB	SBA HyperPro (floating)	nlw, Rrs		
UMB	Profiling IOP package	various IOPs		
UMB	Spectral Evolution Handheld	Rrs		
UMB	IFCB flowcytobot	DATA NO GOOD - WILL NOT DELIVER	NO	NO
HBOI_Twardowski	MASCOT IOP profiling package	many parameters		
Stennis/USM & NRL	Underway IOPS	bb, c, ap, ag, etc.		
Stennis/USM & NRL	Handheld ASD	Rrs		
Stennis/USM & NRL	Floating Hyperpro	nLw, Rrs, other parameters on package		
Stennis/USM & NRL	Secchi Disk			
U. Miami	NURADS			
OSU	HyperPro profiling	nLw, Rrs, etc. on package		
OSU	Spectral Evolution Handheld	Rrs		
NIST	n/a	n/a		

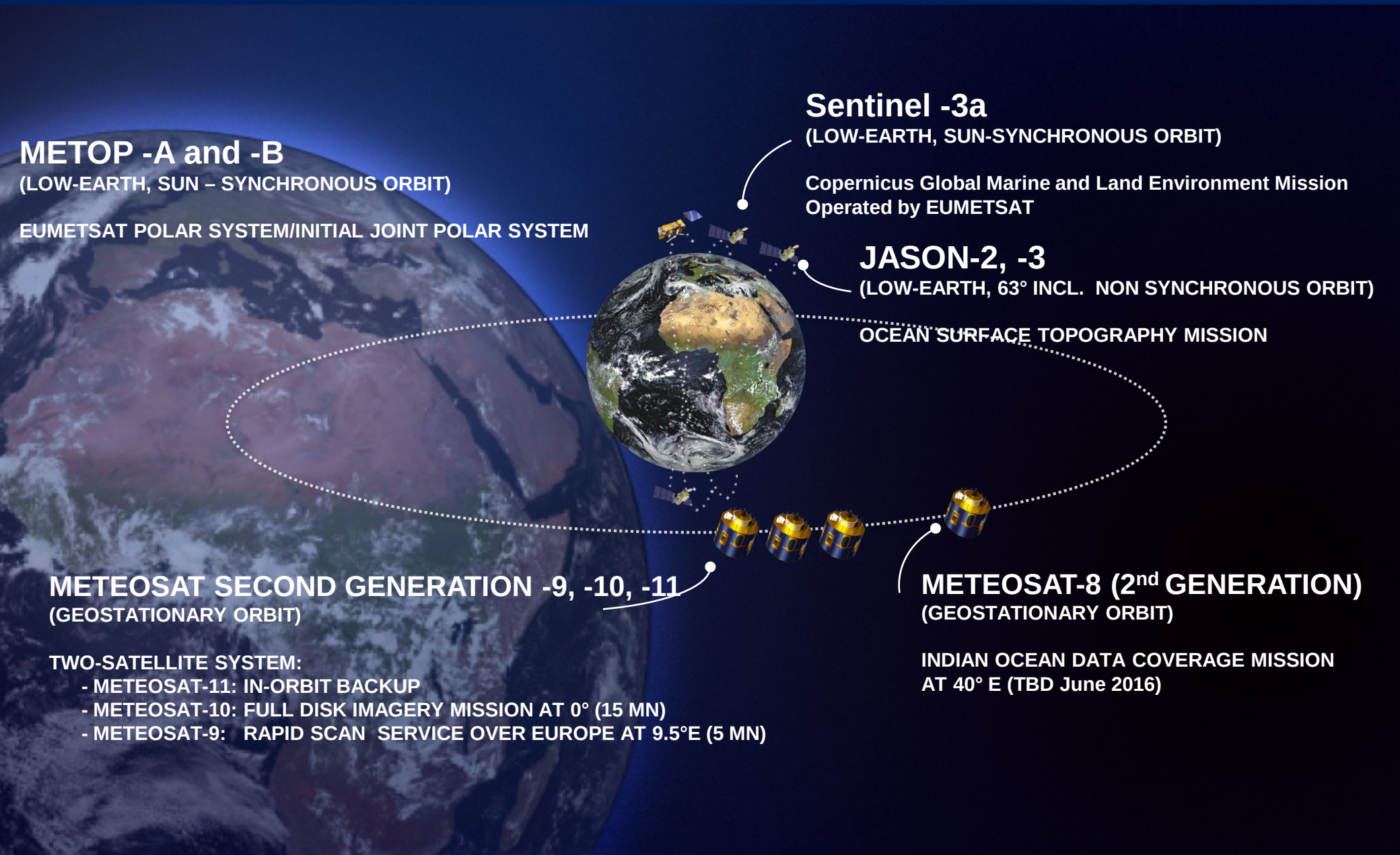
VIIRS/OLCI Cooperation

Bojan R. Bojkov

and the Marine Applications team



The Current EUMETSAT satellite fleet



METOP -A and -B
(LOW-EARTH, SUN – SYNCHRONOUS ORBIT)

EUMETSAT POLAR SYSTEM/INITIAL JOINT POLAR SYSTEM

Sentinel -3a
(LOW-EARTH, SUN-SYNCHRONOUS ORBIT)

Copernicus Global Marine and Land Environment Mission
Operated by EUMETSAT

JASON-2, -3
(LOW-EARTH, 63° INCL. NON SYNCHRONOUS ORBIT)

OCEAN SURFACE TOPOGRAPHY MISSION

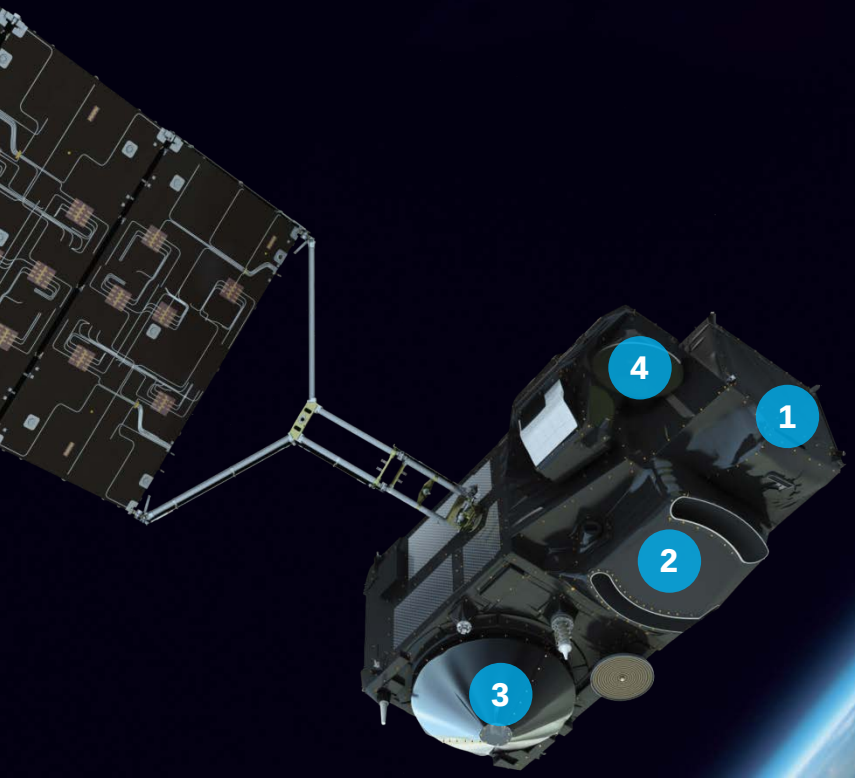
METEOSAT SECOND GENERATION -9, -10, -11
(GEOSTATIONARY ORBIT)

TWO-SATELLITE SYSTEM:
- METEOSAT-11: IN-ORBIT BACKUP
- METEOSAT-10: FULL DISK IMAGERY MISSION AT 0° (15 MN)
- METEOSAT-9: RAPID SCAN SERVICE OVER EUROPE AT 9.5°E (5 MN)

METEOSAT-8 (2nd GENERATION)
(GEOSTATIONARY ORBIT)

INDIAN OCEAN DATA COVERAGE MISSION
AT 40° E (TBD June 2016)

Copernicus Sentinel-3



Launched: 16 February 2016

10:00 local, desc. orbit (98.6º)

Instruments:

1. **OLCI**
   Ocean and Land Colour Instrument
2. **SLSTR**
   Sea and Land Surface Temperature Radiometer
3. **SRAL**
   SAR Radar Altimeter
4. **MWR**
   Microwave Radiometer

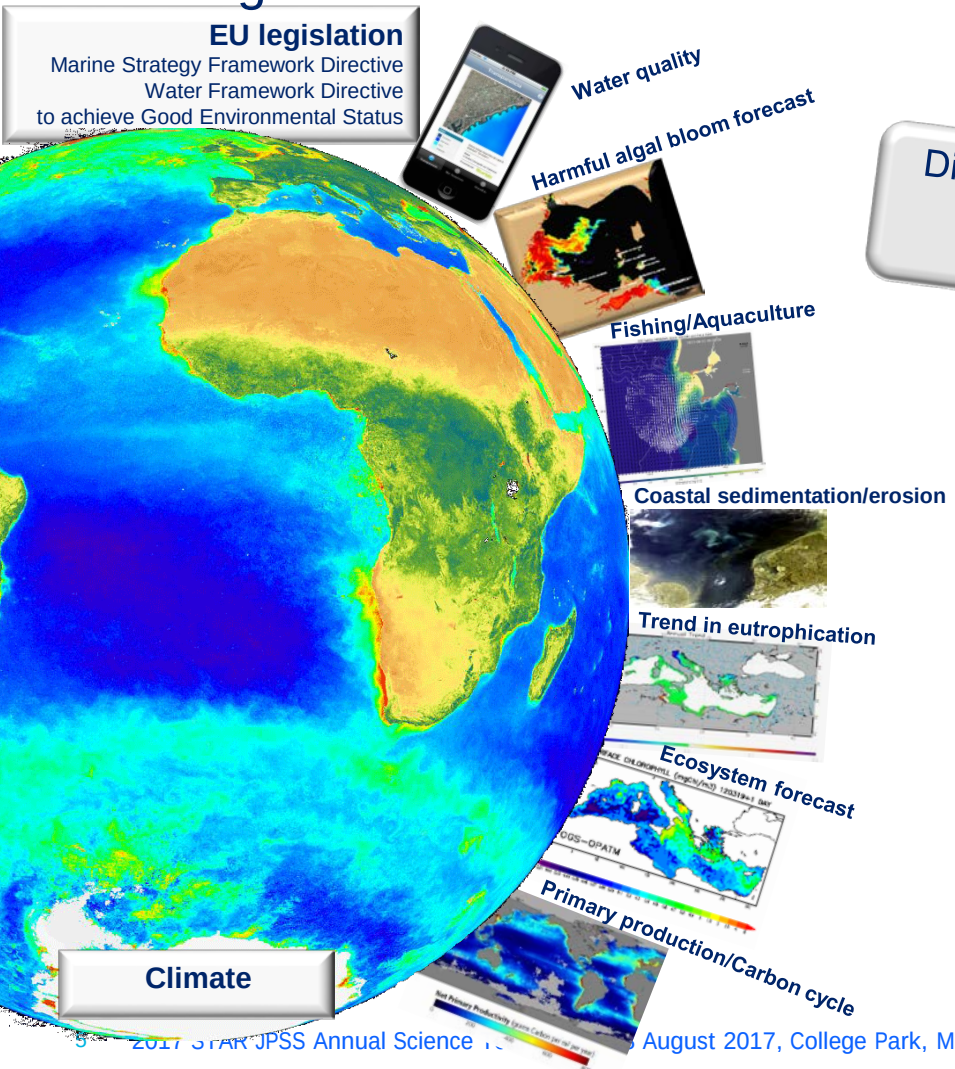
Ocean Colour Radiometry @ EUMETSAT

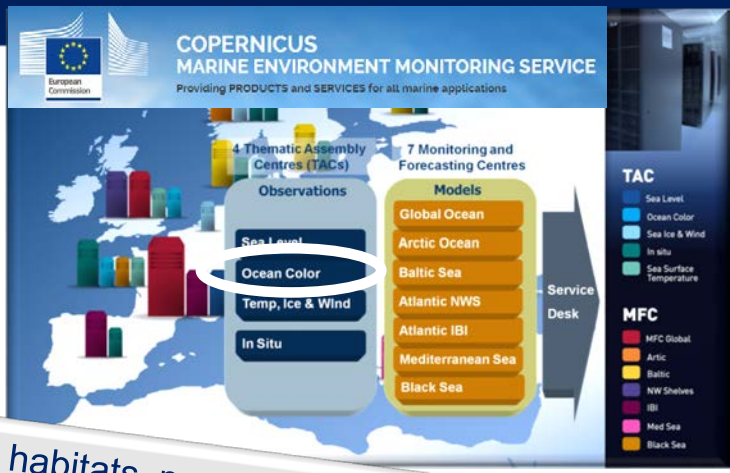
- **Context**
  - Ocean Colour is a new user community for EUMETSAT
  - EUMETSAT delegation for Copernicus S3 marine data services by the European Commission (EC)
  - The main customer is the Copernicus Marine Environment Monitoring Services (CMEMS)

- **Priority Objectives**
  - Deliver fully characterized operational products from the OLCI-A-B (and C-D in the future) constellation
  - Evolution of S3 OLCI operational products
  - Establishment of a European Vicarious Calibration infrastructure
  - Development of an Ocean Colour Products Portfolio

Ocean Colour – applications and user requirements

- CMEMS – primary user in the Copernicus framework
- Large and diverse user base





Diversity of regional water habitats, processes and constituents =
High variability of optical water properties =
Broad range of applications and users

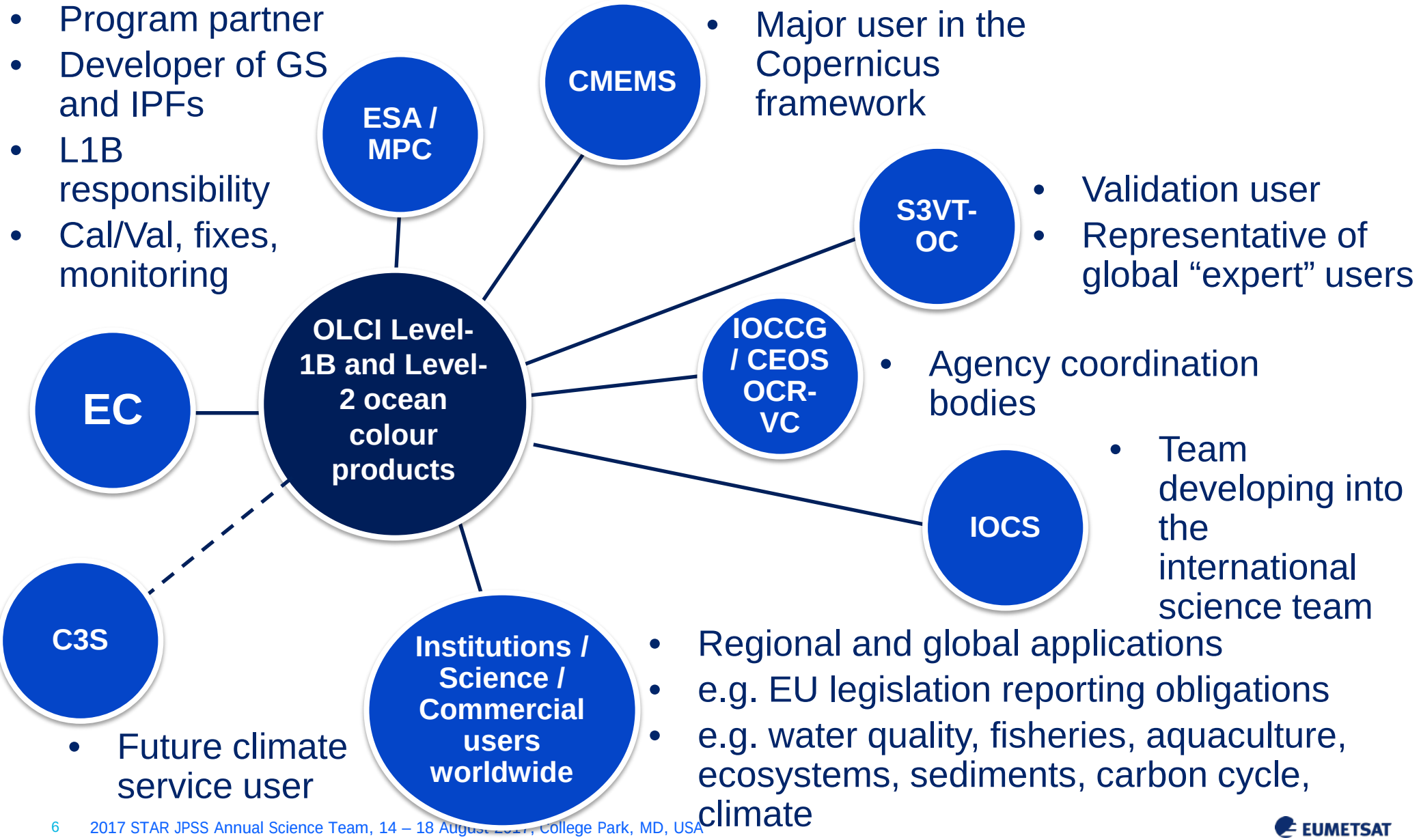
Users request ❶

- relevant products of known high quality
- harmonization, consistency and stability across missions
- focus on coastal and inland waters (in addition to open sea)
- new products

❶ CMEMS, S3VT-OC, IOCS, S3 MAG, GMES-PURE, Copernicus Marine Expert Exchange, Sentinel-3 Mission Documentation (S3 Mission Requirements Traceability Document, S3 Calibration and Validation Plan)

Institutions and community interfaces

Ocean Colour is global and very regional → diverse community



- Program partner
- Developer of GS and IPFs
- L1B responsibility
- Cal/Val, fixes, monitoring

- Major user in the Copernicus framework

- Validation user
- Representative of global “expert” users

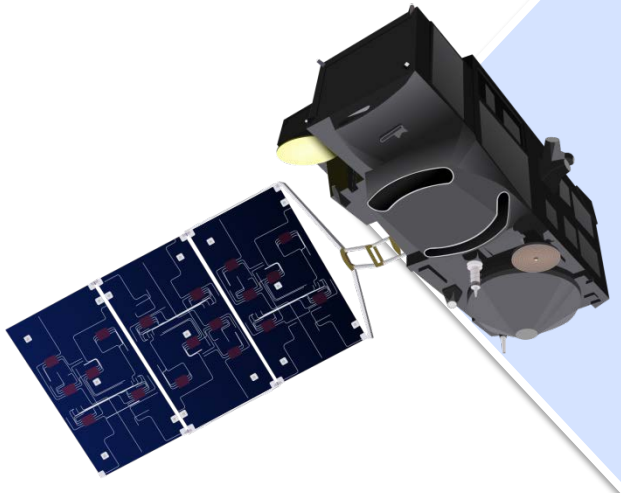
- Agency coordination bodies

- Team developing into the international science team

- Future climate service user

- Regional and global applications
- e.g. EU legislation reporting obligations
- e.g. water quality, fisheries, aquaculture, ecosystems, sediments, carbon cycle, climate

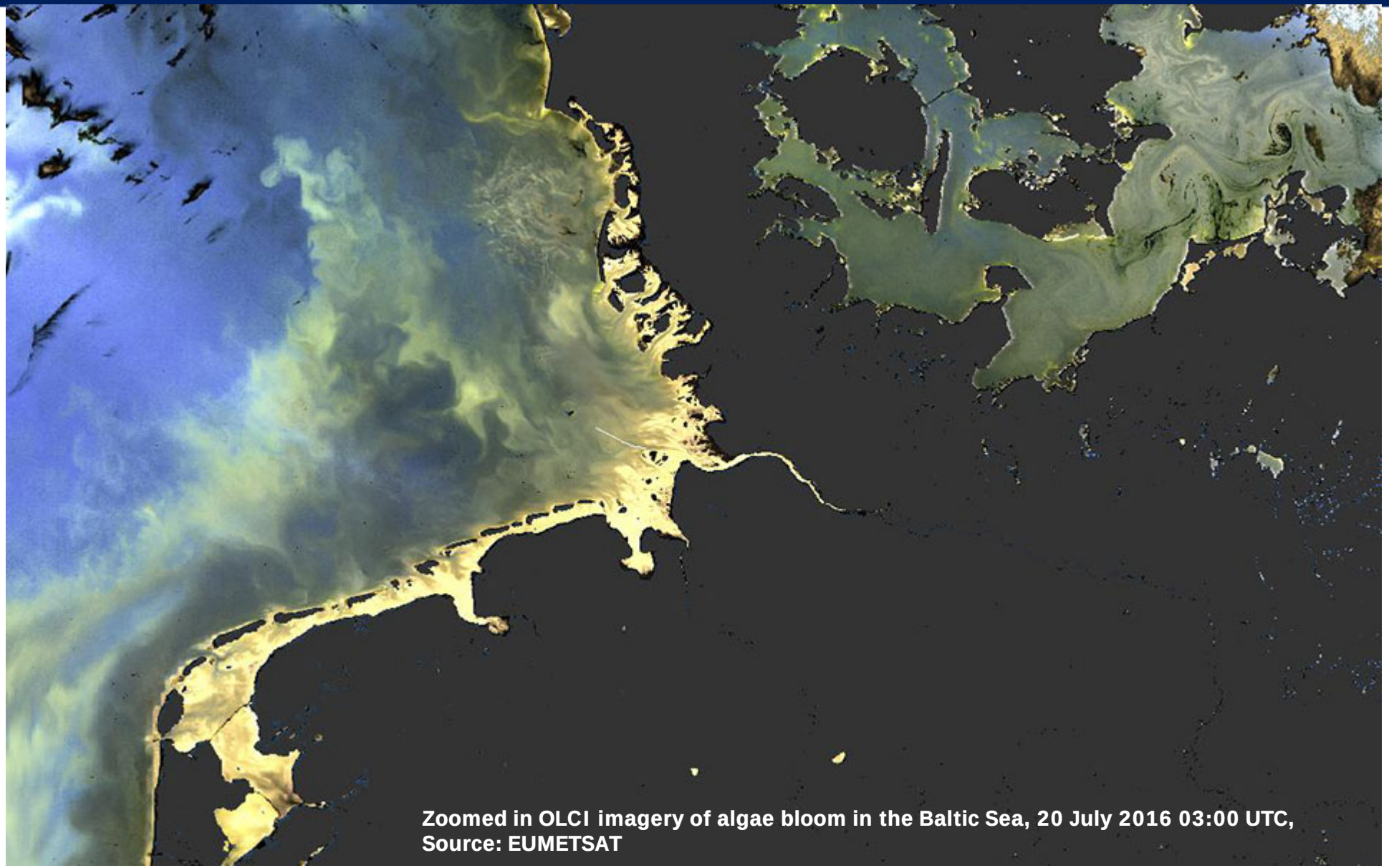
Ongoing tasks at EUMETSAT



Sentinel-3 {A,B,C, D} / OLCI:

- **Cal/Val tasks** based on Joint ESA/EUM S3 Cal/Val Plan
  - Solar diffuser in-flight characterization, completed for S3A
  - Operational scheduling of radiometric calibrations
  - Radiometric stability validations at L3
  - Geometric validation at ground control points
  - Ad hoc in situ FRM validations (MOBY)
  - Validations with L3 (multi-mission/climatology)
  - Product quality verifications (flags, artifacts)
- **Product maintenance** to achieve useable products
  - Fixes for major issues (biases, flags, old MERIS to OLCI,..)
  - REF product validations for new PB releases
  - Test reprocessings/product validations to define new PBs
- **System Vicarious Calibration** (SVC) – development of Copernicus FRM capability required for ocean colour missions to meet user product quality requirements
  - Study 1: Requirements for Copernicus SVC capability

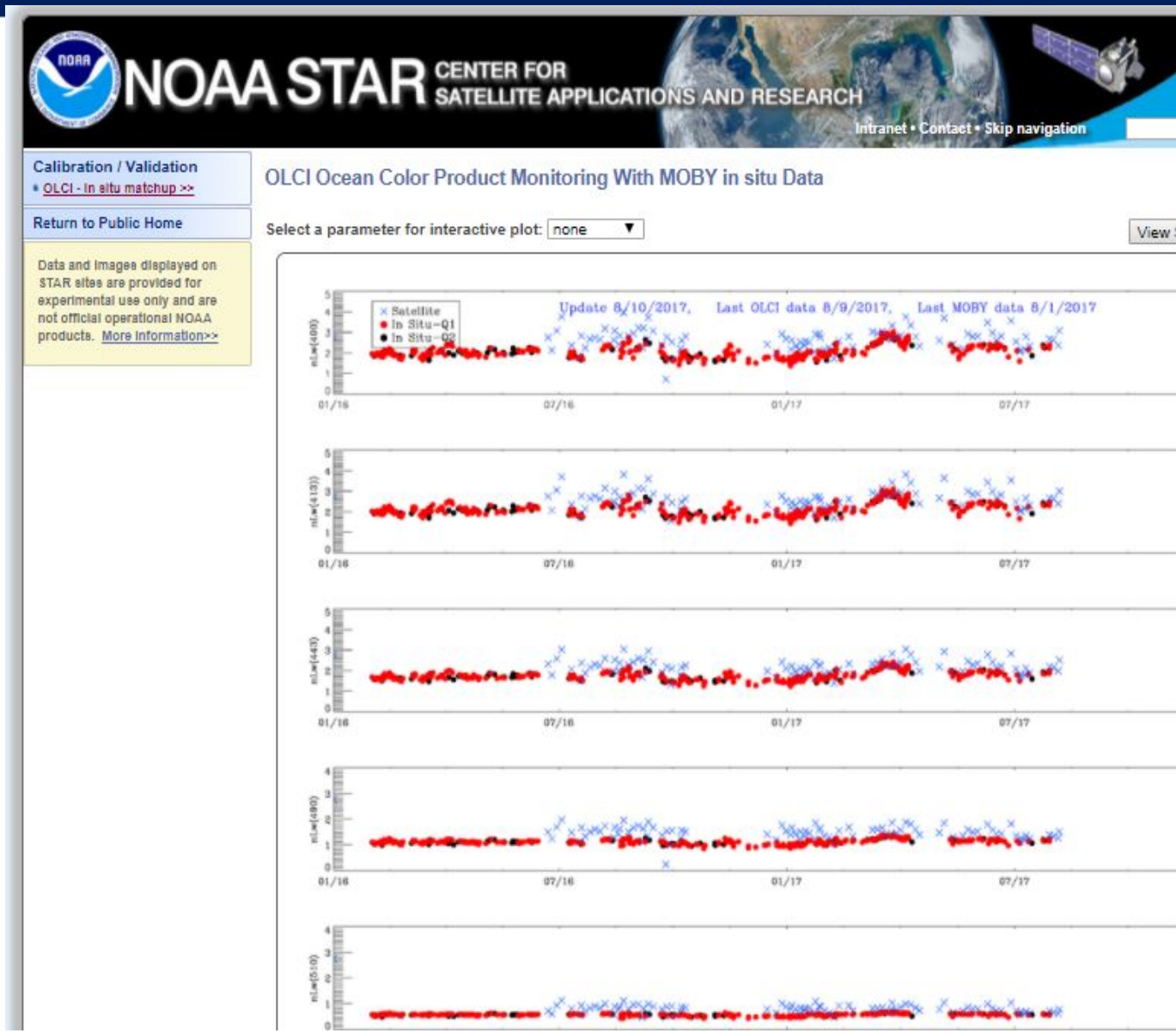
Sentinel-3: OLCI Level 2 products operational



Zoomed in OLCI imagery of algae bloom in the Baltic Sea, 20 July 2016 03:00 UTC, Source: EUMETSAT

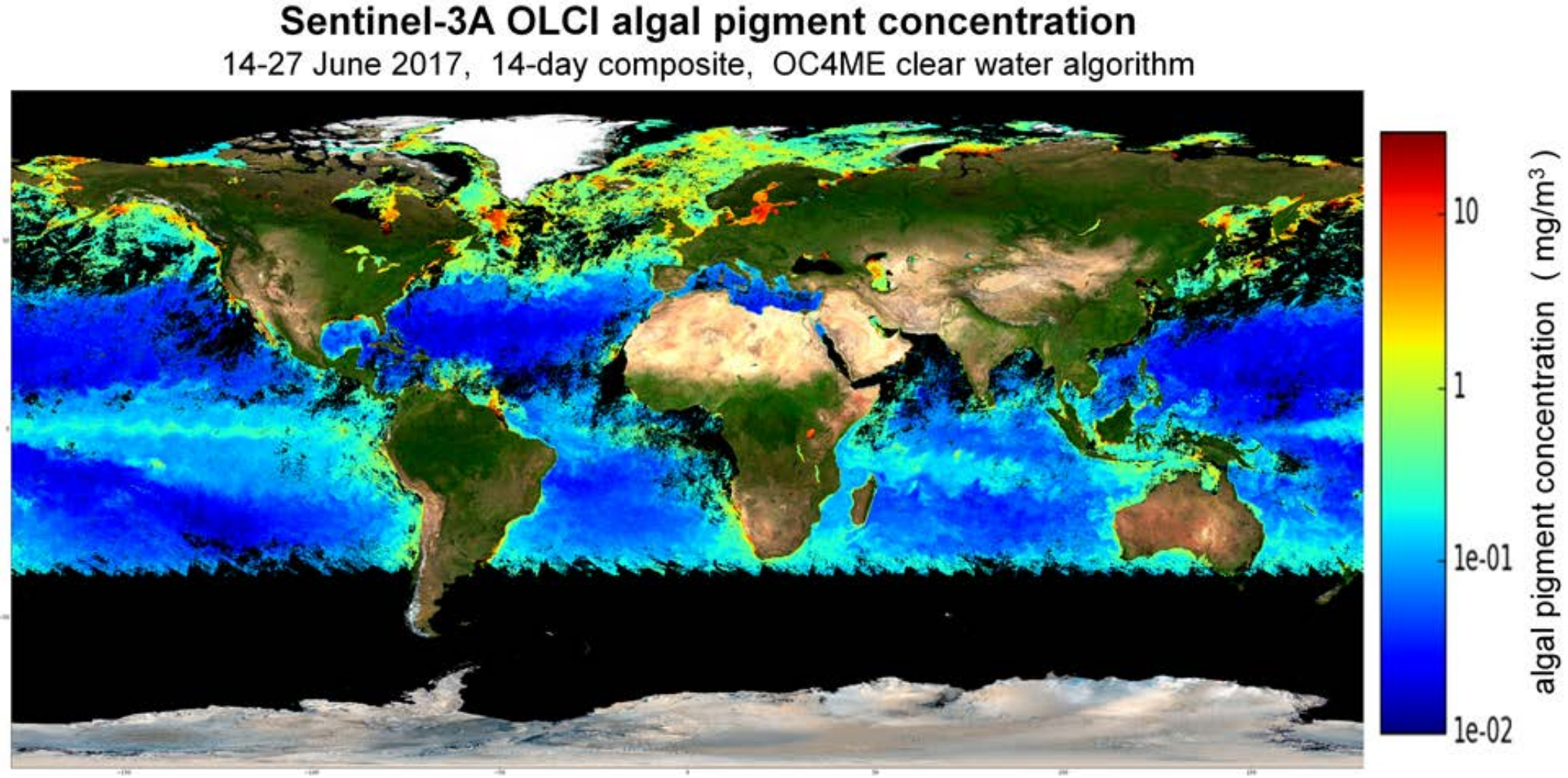
Use of VIIRS NOAA OC data/tools for intercomparisons

- NOAA VIIRS products used extensively to ‘debug’ the initial versions of the L1 and L2 processors and “system” gains provided by ESA
- Tremendous help from the NOAA OC team
- Integration of OLCI into NOAA OC Cal/Val pages – *a very special thanks to Menghua Wang*

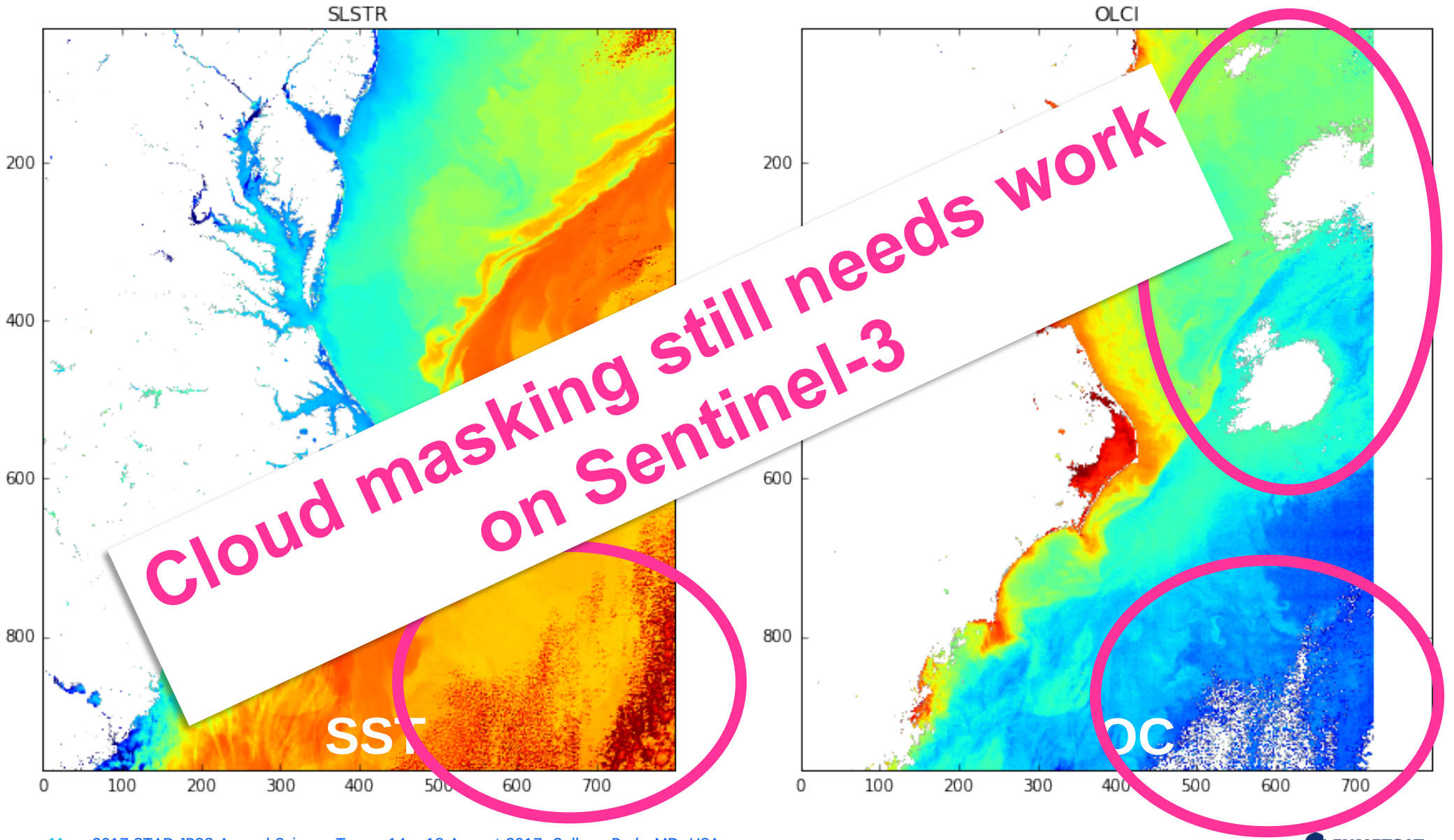


EUMETSAT

Sentinel-3A OLCI Level-2 products operational



Sentinel-3 SLSTR and OLCI L2 operational as of 5 July



EUMETSAT

VIIRS/OLCI cooperation: Ocean Colour Processor

- User Needs
  - Ocean colour users need products with the same characteristics regardless of the scene observed. This applies to the water-leaving radiances as well as the optical and bio-geo-chemical properties;
  - The atmospheric correction process shall have open ocean, coastal and inland water competency, ensuring consistent correction above clear as well as turbid waters;
  - The in-water product shall be multi-water consistent across clear and turbid;
  - The L2 product shall include directly usable quality information and expression of parameter uncertainties.

- Approach
  - A new independent development, implementing the state of the art, IPR-free such as for example the ESA CCI legacy;
  - Open source and active involvement of the global expert community, via community code and independent peer reviews;
  - Flexible framework easing transition from prototype to operational processor, supporting expansion of products portfolio → *agile development*
  - Design with applicability to other missions e.g. geostationary

VIIRS/OLCI cooperation: OC FRM Infrastructure

OC Fiduceal Reference Measurement (FRM) = “European MOBY”

- For OC missions, the system vicarious adjustment is critical to meeting the mission accuracy requirements;
- Vicarious adjustment capability is critical for the long-term operational Copernicus and JPSS Programmes to provide quality Ocean Colour products and services;
- Sustained European infrastructure(s) are essential for the long term and complimentary to the NOAA MOBY activities.
- Key requirements include: high accuracies and SI-traceability of the optical radiometer system, minimal environmental uncertainties -marine and atmospheric- at the deployment site, and operational performance to support calibrated time-series over a few decades.

VIIRS/OLCI cooperation: OC FRM Infrastructure (ii)

Approach for the OC FRM:

Step 1: Community driven requirements/specifications

Has been implemented by a EUMETSAT-led Copernicus study establishing the highest level applicable scientific, technical and operational requirements that form the basis for the development of a Copernicus Infrastructure for Ocean Colour Vicarious adjustment. This study was run in liaison with the ESA study ”QA4EO FRM4SOC” focusing on the development of best practises for these FRMs for satellite ocean colour validation, and the international OC community (reviews)

Step 2: Preliminary design

Three studies will run in parallel in order to compare thoroughly the possible approaches/designs in the 2017-2018 time frame. Again, international review of the preliminary design will be undertaken.

Step 3: Final design and deployment

The concept selected at the conclusion of Phase 2 will be developed into a detailed technical design specification in the 2019 time frame, with a deployment in 2021 timeframe pending final budgetary approval by the European Commission.

Summary

- NOAA OC team critical to OLCI OC gaining operational status at EUMETSAT, through intercomparisons, Cal/Val, personnel exchanges, etc.

- Future EUMETSAT-NOAA cooperation on OC:
  - Continue on-going L1 and L2 activities
  - Start work together on the community OC processor (*and the related Cal/Val tools)*
  - Help define future European OC FRM infrastructure
  - To be formalised by year end

Ocean Color in Operational Ocean Forecast Systems

Avichal Mehra[1], Sudhir Nadiga[1], Hae-Cheol Kim[1], Vladimir Krasnopolsky[1], and Eric Bayler[2]

[1]NOAA / NWS / NCEP /EMC

[2]NOAA / NESDIS / STAR

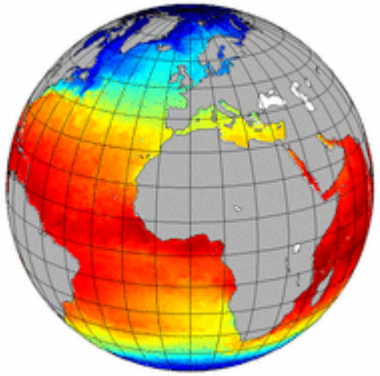


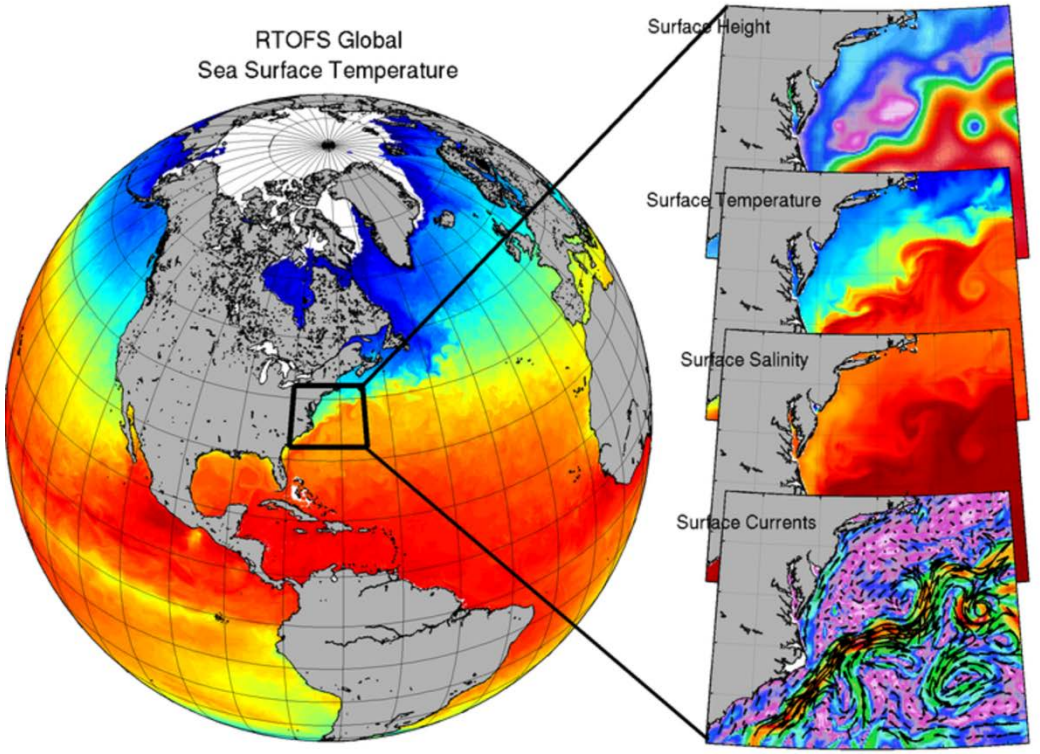
JPSS/PGRR Meeting, August 16, 2017

Outline

- Background
- Overall objectives
- Interesting results
- Operational Plans
- Ongoing Work

Real-Time Ocean Forecast System (RTOFS)





- Operational configuration of RTOFS

  - Hybrid Coordinate Ocean Model (HYCOM) with 1/12º horizontal resolution and 41 hybrid layers
  - Iso-pycnal (deep ocean), z-levels (surface), σ (coasts)
  - NAVOCEANO daily initialization with MVOI (now 3DVAR) data assimilation from NCODA (Navy's Coupled Ocean Data Assimilation)
  - Daily 2-day nowcast (GDAS) and 8-day forecasts (GFS)

Graphics by Todd Spindler

Current Ocean Color Projects
(funded by JPSS-PGRR program)

Titles :

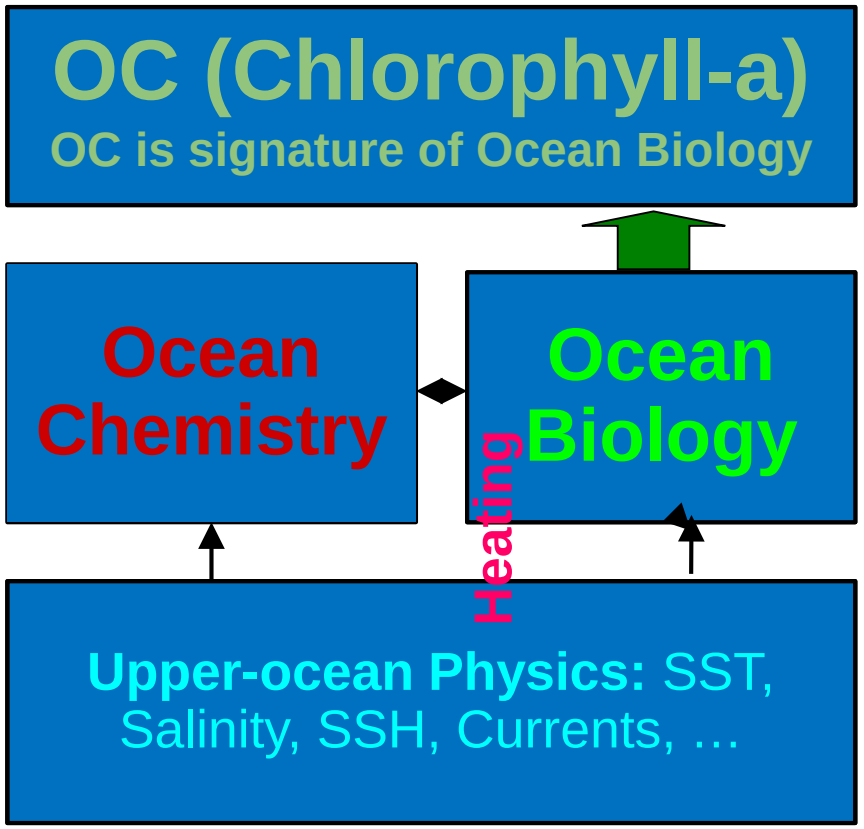
- Using Neural Networks for gap-filling and preliminary short-range (1-2 weeks) to medium-range (3-4 weeks) predictions of satellite-derived ocean color fields (Chl-a, Kd_{490} and Kd_{PAR})
- Initial biogeochemical modeling at NOAA/NCEP: Using VIIRS ocean color data for validation and data assimilation

Main priorities:

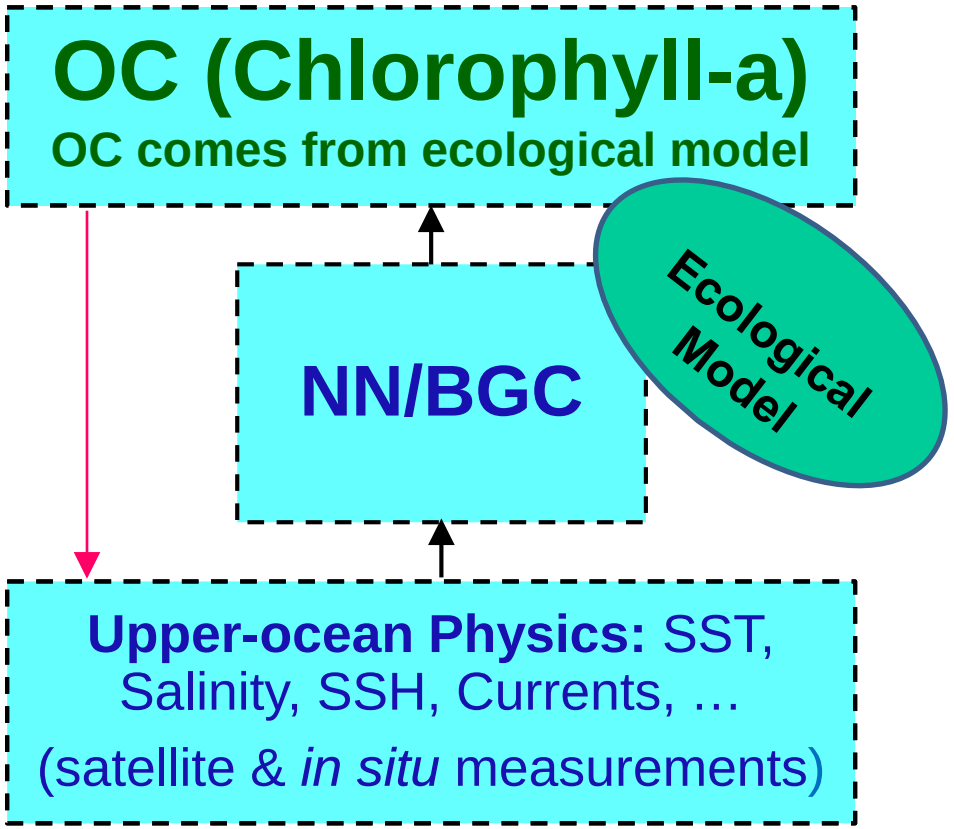
- Update OC fields for Ocean Data Assimilation (NCODA)
- Predict OC fields for feedback during forecast cycle

Ocean Color & NN/BGC

Ocean Processes



NN/BGC emulation



FEEDBACK FROM OCEAN BIOLOGY (COLOR) TO UPPER-OCEAN HEATING IS IMPORTANT FOR OCEAN/COUPLED FORECASTING

Overall Objectives

1. **Ocean Color (OC) integration in operational ocean and coupled modeling**
    - Ingest NRT and Science quality data: OC data in ocean models for physical and biological processes

      Application: Improve short-term Operational Ocean Forecasts
    - Consistent Gap-Filled OC values across multiple satellite missions for use in long ocean reanalysis efforts

      Application: Neural Network (NN)-based consistent gap-filled Ocean Color

2. **Make Short-Term (1-2 weeks) to Medium-Term (3-4 weeks) Ocean Color Predictions**

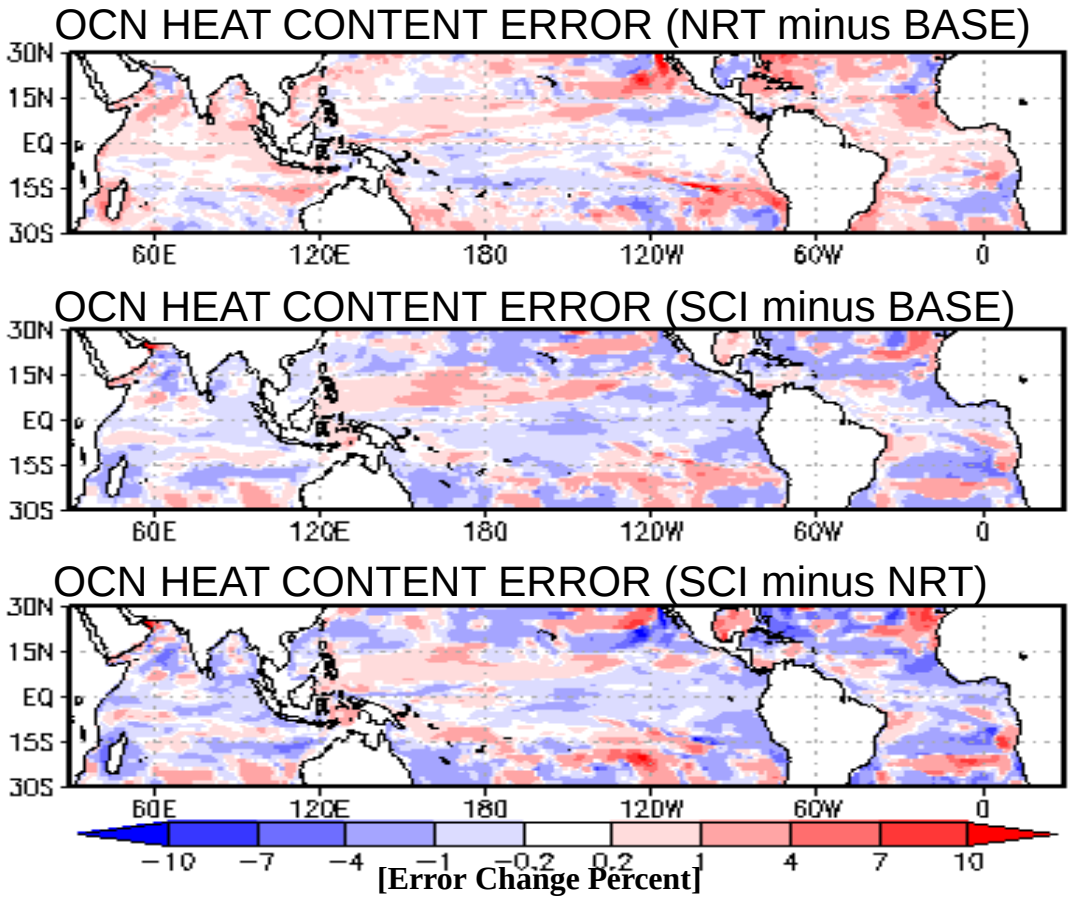
    Application: Short-term to Medium-term Operational Ocean Forecasts

3. **Bio-Geo-Chemical Modeling with Ocean Color inputs**

    Application: Use Ocean Color Fields for estimating 3D Ocean BGC ocean states

    Application: Boundary and initial conditions for Coastal OFS (inputs for NOS, NMFS)

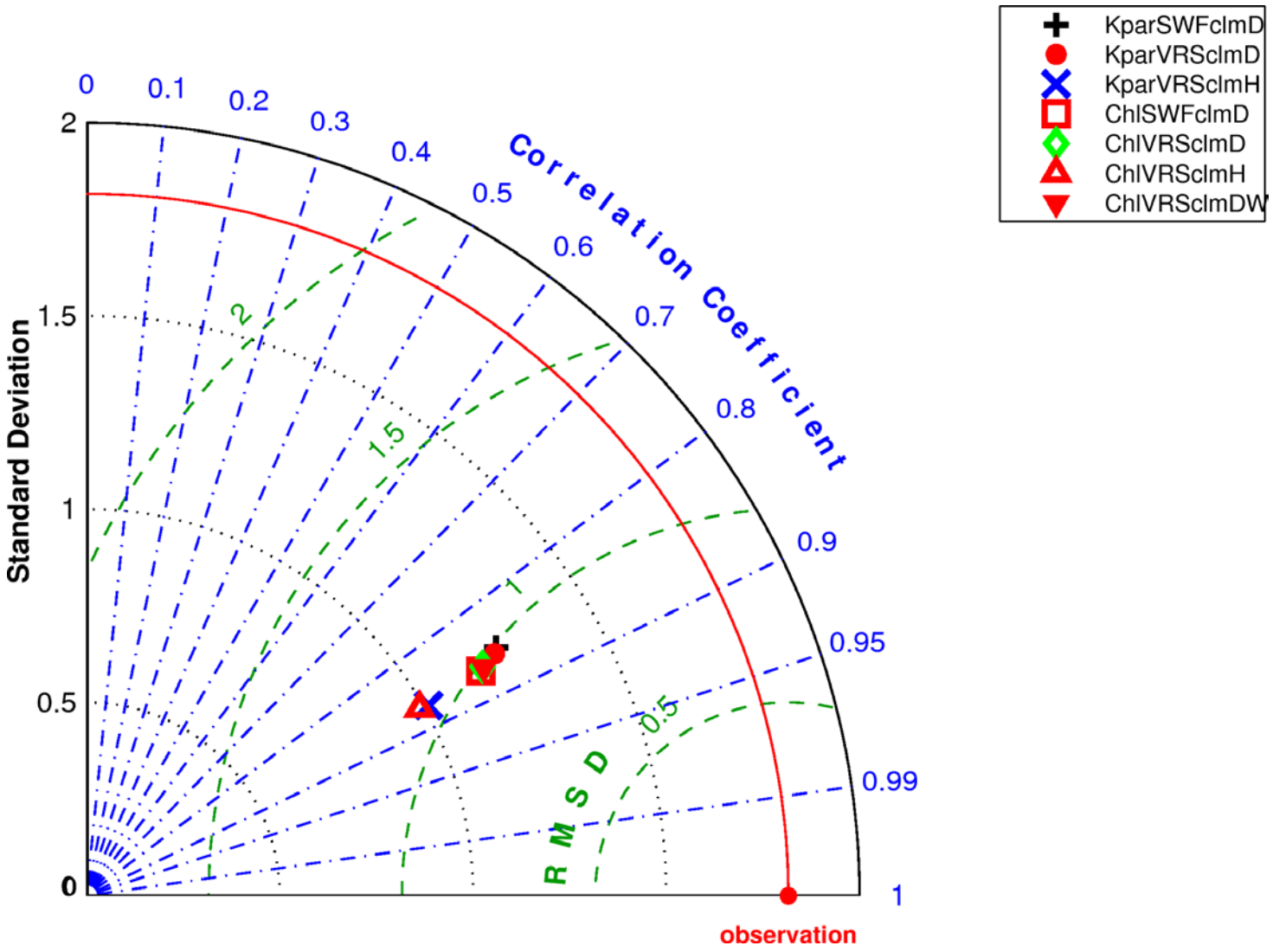
OCEAN COLOR IN OCEAN MODELING



NESDIS Science-quality Chlorophyll-a significantly outperforms NRT and BASE in ocean model simulations; GODAS analyses used as observations;

BASE is model run with SeaWiFS 4-yr monthly climatology; SCI is run with VIIRS science-quality OC; NRT is run with VIIRS NRT OC (all based on 4 year experiments 2012-2015)

SST Verification against GODAS for NINO 3.4 (170W-120W; 5S-5N)

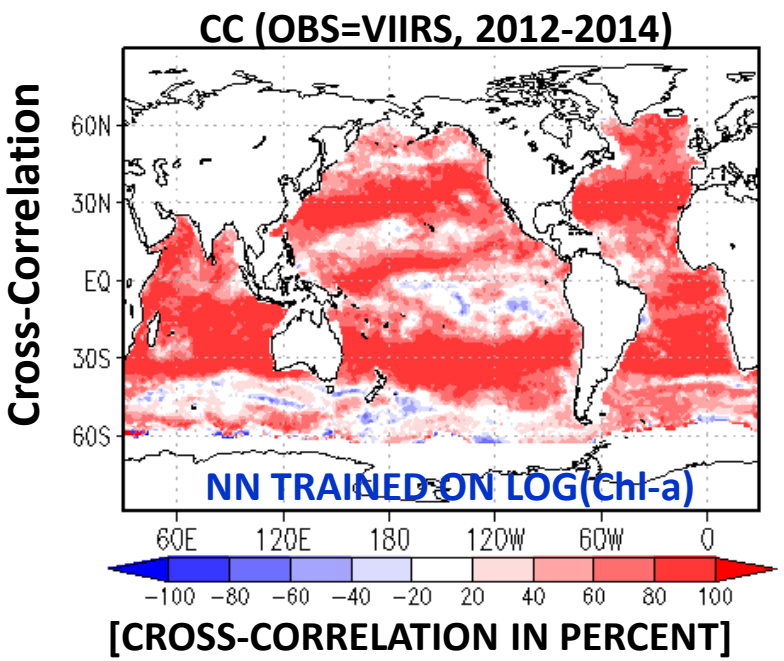


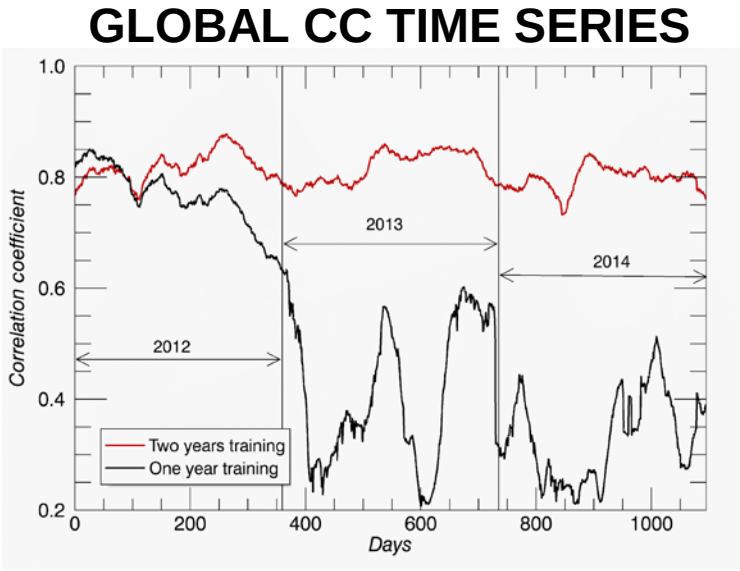
- Algorithmic impact (Chl vs Kpar) is not as big as expected (e.g., SeaWiFS case) when daily-averaged forcings were used
- When diurnal variation is resolved (hourly forcings used) both Kpar and Chl algorithm yielded different results from the others



(www.climate.gov/)

NEURAL NETWORK PERFORMANCE





NN is able to capture OC variability reasonably well over most of the global oceans for training period > 2 years.

Operational Plans with Ocean Color

Integrating Ocean Color in RTOFS:

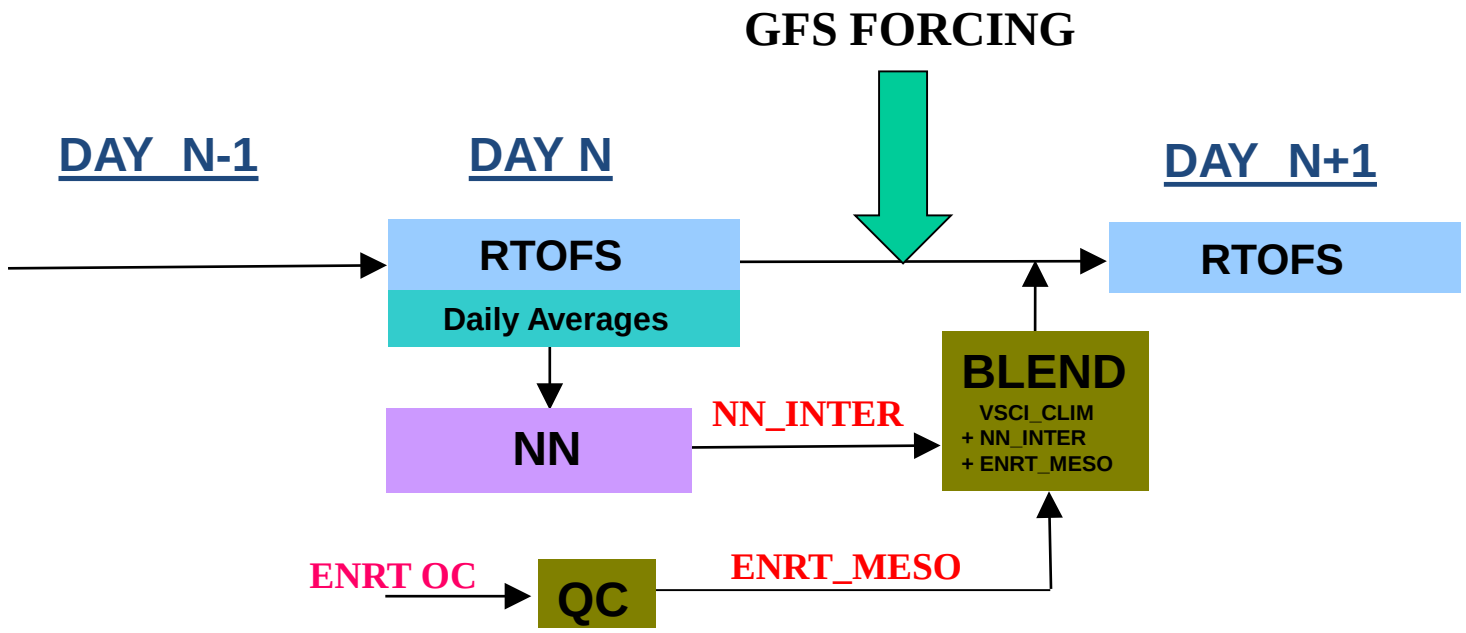
(1) Use Statistical (NN) Model

Blend of mean, low-frequency variability, high-frequency variability
Advantage: Being tested for next operational RTOFS upgrade/impacts

(2) Use Biogeochemical Model

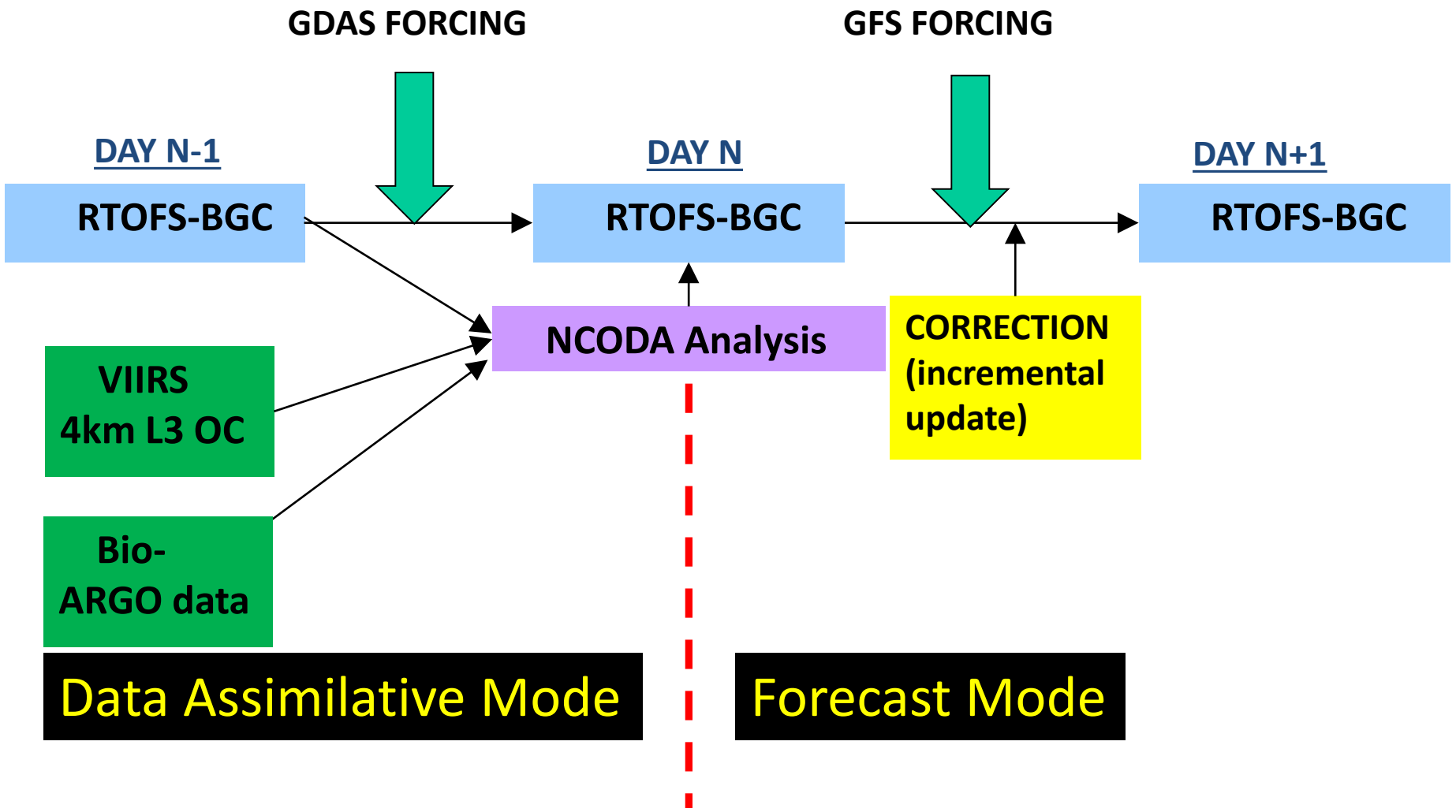
Use BGC model with NCODA/RTOFS.
Advantage: Provides full 3-d ocean biological state

Statistical OC Model in RTOFS
Schematic View



BLEND: MIXES MEAN (VSCI_CLIM), LOW-FREQUENCY (NN_INTER) AND HIGH-FREQUENCY (ENRT_MESO) OC VARIABILITY

Biogeochemical OC Model in RTOFS Schematic View



Current Status: NN Ocean Color Project

Objective: Ocean Color for Operational Ocean Forecast Systems:

(1): Preliminary assessment of NESDIS NRT and science-quality OC in ocean models (completed).

(2): Testing NN model for coupling to RTOFS (on-going).

FY 18 Targets:

(1): Testing for operational upgrade of RTOFS with embedded NN (on-target)

(2): Role of ocean color in SST predictions over weather time scales (on-going).

Current Status: Biogeochemical Modeling Project

Objective: Ocean Color for Operational Ocean Forecast Systems:

(1): Science quality VIIRS products and thermal structure effects on BGC variables (completed)

(2): In-line coupling of NPZD-type ecosystem model in HYCOM/RTOFS (completed)

FY 18 Targets:

(1): Ocean color (VIIRS science quality) data assimilation (2DVAR) in RTOFS-BGC-NCODA (on-going)

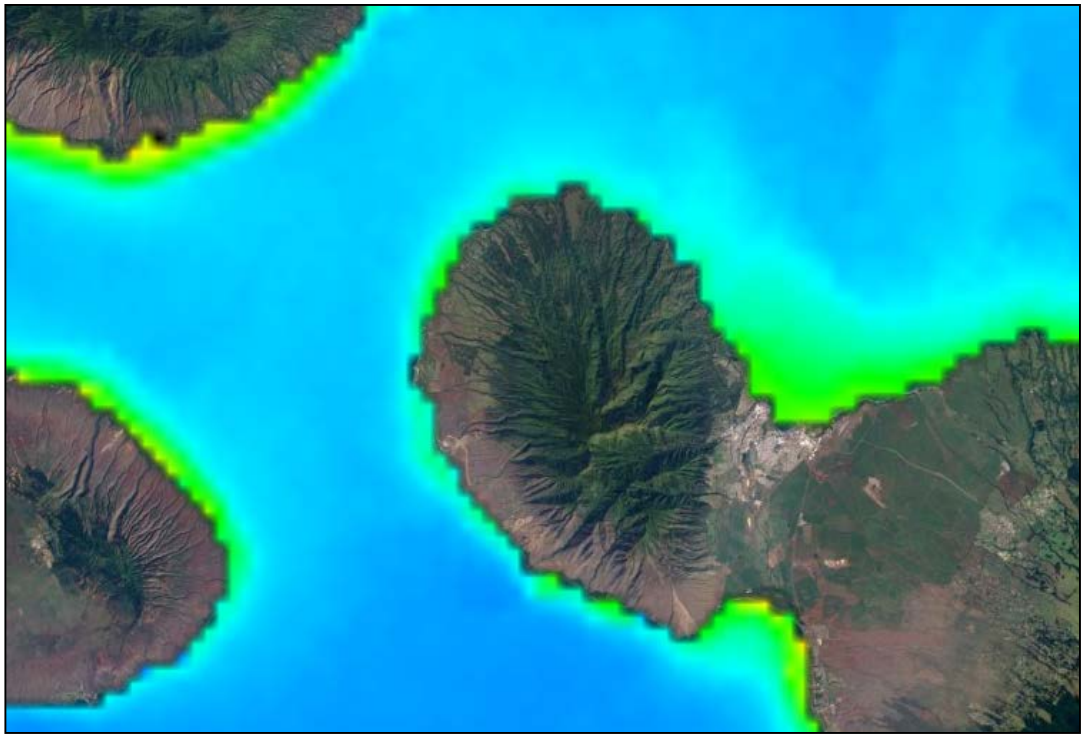
(2): Implementation of physical/biogeochemical variables (3DVAR) in RTOFS-BGC-NCODA (on-target)

(3): Exploring added complexities (e.g., 9-component BGC model which includes carbon and dissolved oxygen sub-modules) (TBD)

Thank You !

Satellite-based Ocean Color Tools for Coral Reef Management

Erick Geiger, William Hernandez, Brianna Craig, Rob Warner, Alan E. Strong, C. Mark Eakin, Menghua Wang, Jacqueline L. De La Cour, Gang Liu, Kyle Tirak, Scott F. Heron, William J. Skirving



STAR JPSS Annual Team Meeting
August 16, 2017 - NCWCP, College Park, MD

STAR Ocean Color
Global Science & Technology, Inc.
University of Puerto Rico Mayagüez Campus
University of Hawai'i Maui College
NOAA Coral Reef Conservation Program

Ocean Color
How can it help coral reef managers?

The color of coastal water is related to water quality.

Satellite ocean color data provide a synoptic view of water quality.

Of the many satellite ocean color products, two are most commonly used for monitoring water quality:



Brown water in Honokahua Bay, West Maui in January 2015. Photo credit: Bill Rathfon.

Chlorophyll-*a*
Represents phytoplankton biomass and nutrient status (**productivity**) as an index of water quality.

K_d(490)
The diffuse attenuation coefficient at 490nm (or light blue in the visible spectrum).

Total organic and inorganic matter held in solution and suspension (**turbidity**) within the water column.

Review

Goal:
Provide satellite products for monitoring land-based sources of pollution over coral reef environments tailored to managers' feedback.

FY13/14:
NOAA NESDIS STAR's Ocean Color Team and NOAA Coral Reef Watch conduct "proof of concept" pilot effort using daily ocean color data from the Visible Infrared Imaging Radiometer Suite (VIIRS) matched with large rainfall events. Study areas include Southern Puerto Rico (Guánica) and West Maui (Ka'anapali) watersheds.

FY15/16:
VIIRS data updated to "science quality" and spatial resolution of products enhanced. Begin creating virtual monitoring areas and experimental anomaly products. Cal/Val efforts are advanced with Puerto Rico partners and initiated with West Maui partners.

Review

FY16/17:
Held workshop in West Maui for local watershed manager feedback and to expand user group. Provided student intern with lab equipment for collecting *in situ* water quality data. VIIRS MLS12 v1.21 reprocessing.

Ongoing:
Continue development of virtual monitoring areas. Develop multi-sensor approach with Landsat 8, Sentinel-2. Expand managers' workstation and populate with new VIIRS data, including 375m resolution data.

Study Area

U.S. Coral Reef Task Force priority watershed sites:

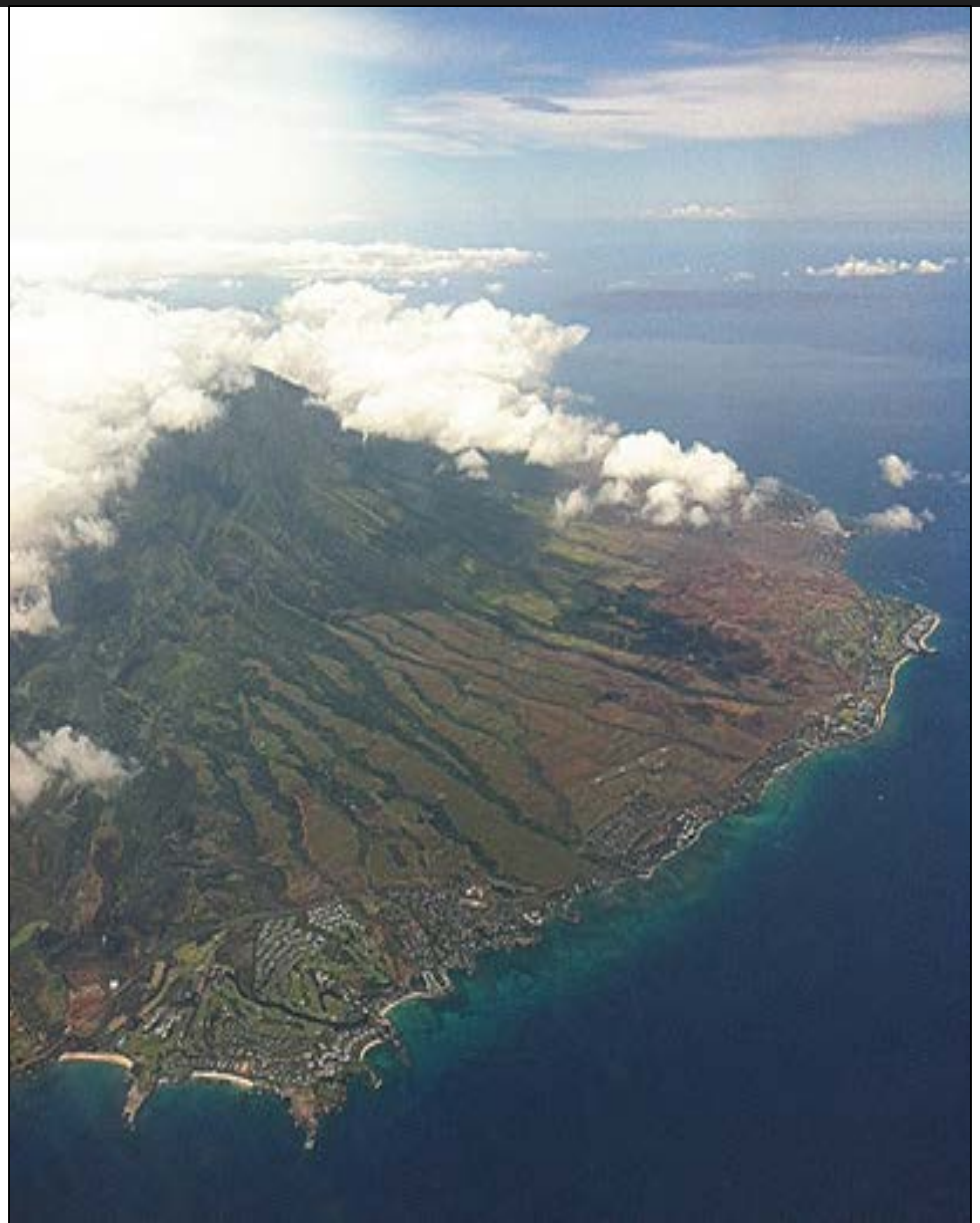
- Ka’anapali (West Maui, Hawai'i)
- Faga'alu (American Samoa)
- Guánica Bay (Puerto Rico).



Image credit: NOAA/NESDIS/STAR/CRW

Study Site
West Maui – Five Watersheds

- Three distinct management zones: Urban, Agricultural, Conservation
- Anticipating land use change in the next decade



West Maui North
Runoff Example - Mid January 2016



Photo credit: Multicopter Maui

West Maui Airport Watershed (Central)



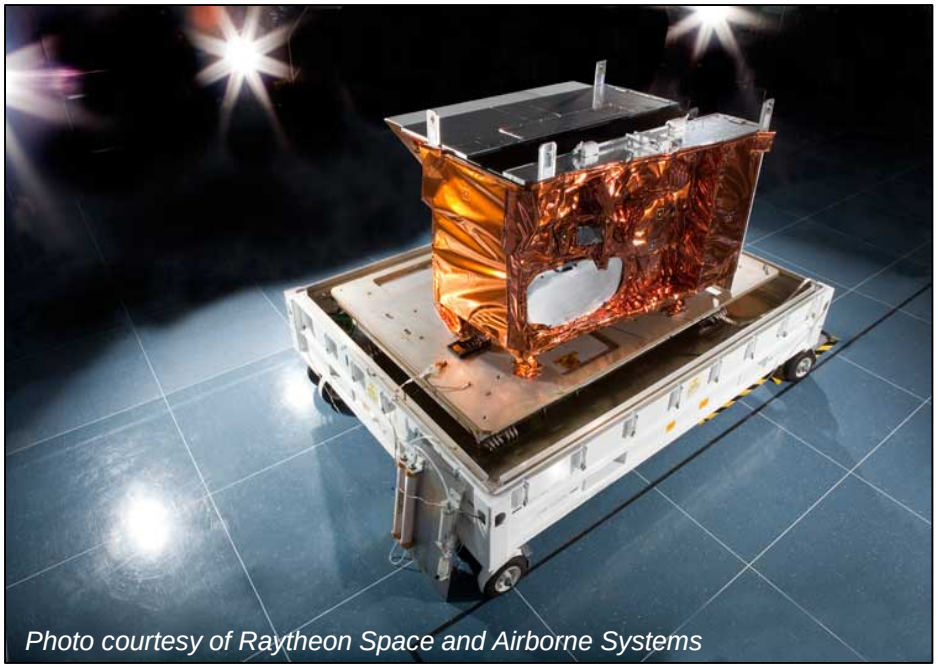
West Maui Hotel Complex (South)



Role for Ocean Color Project

- Which drainages are the biggest source of stressors (nutrient and sediment)?
- How long does sediment persist?
- What are the circulation patterns?
- Which drainages are triggered at what rainfall intensity?
- Can we observe improvements after mitigation on land?

Visible Infrared Imaging Radiometer Suite (VIIRS)


Photo courtesy of Raytheon Space and Airborne Systems

Provides ocean color data at ~750m resolution.

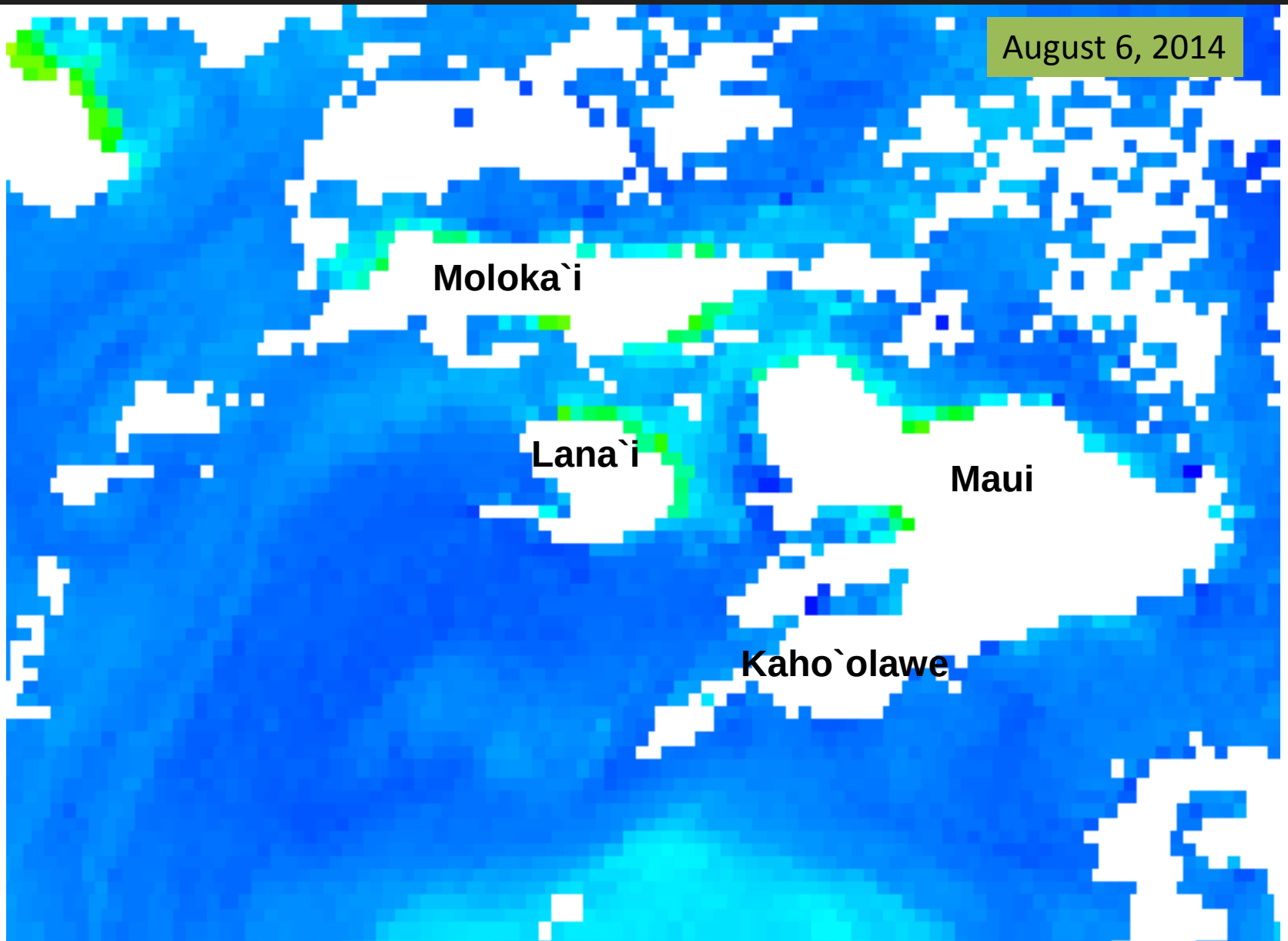
Daily, afternoon pass. One pass a day (no ocean color at night).

Science quality data delayed 2 weeks. Near real-time data is delayed 1 day.

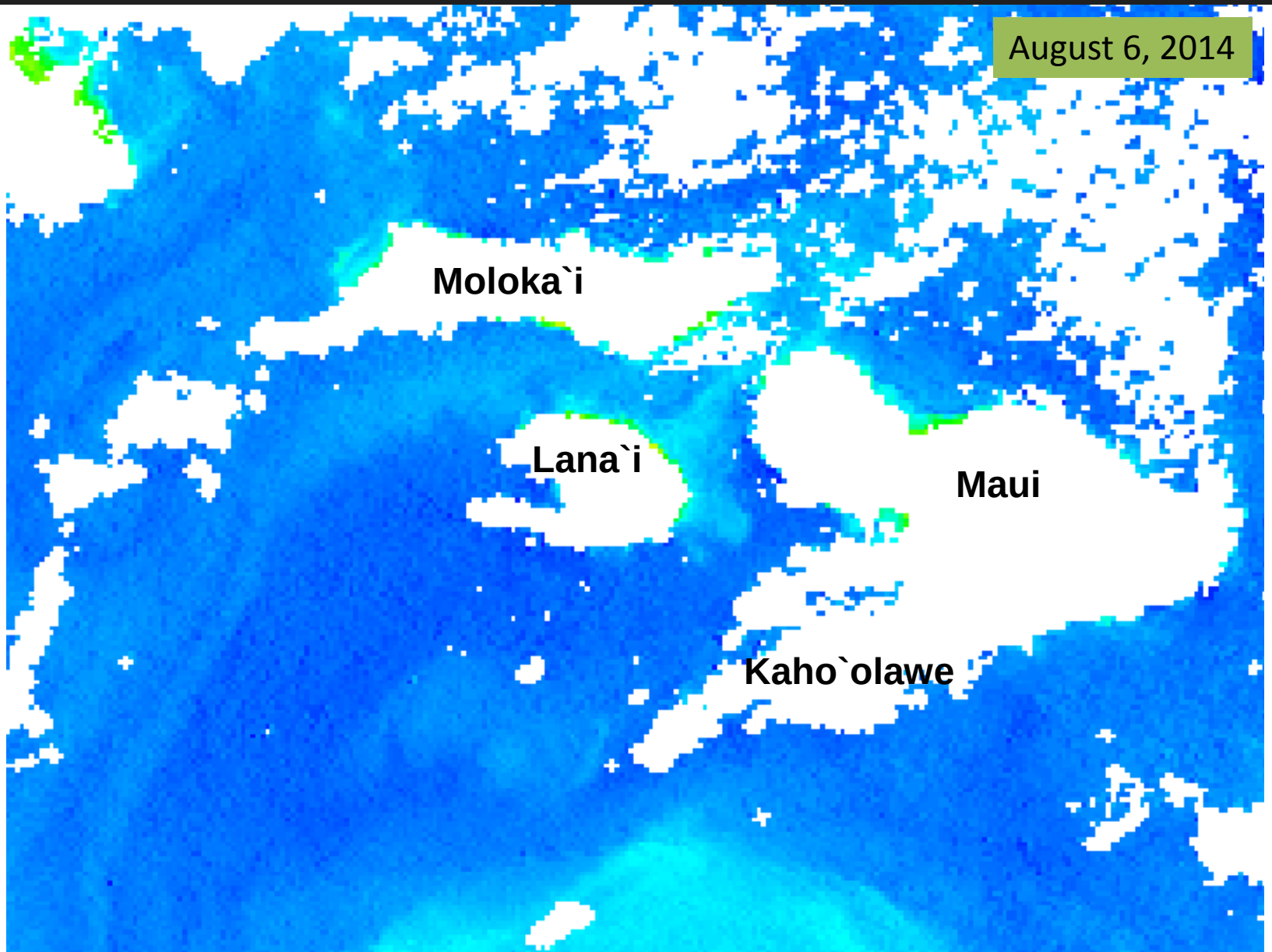
Geophysical data:

Chlorophyll-*a* (mg/m^3)
$K_d(490)$ (m^{-1})
$K_d(PAR)$ (m^{-1})
Normalized water-leaving radiance at:
410, 443, 486, 551, 671nm ($mW/cm^2/um/sr$)

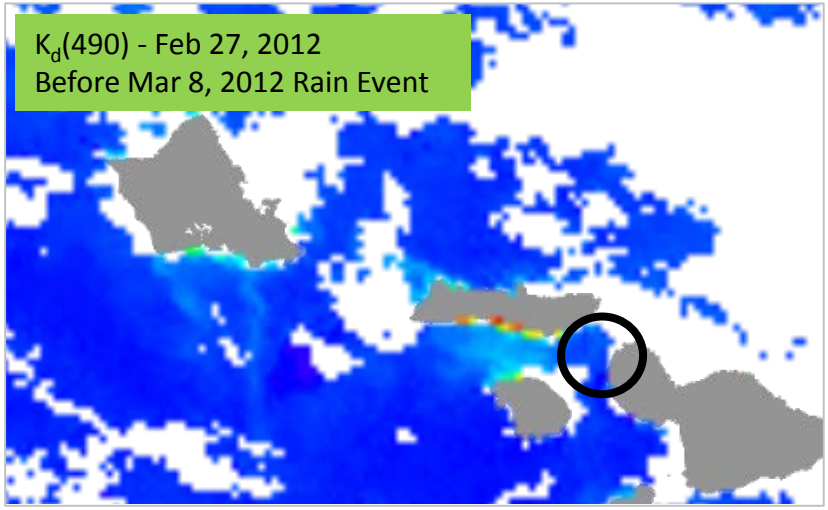
Visible Infrared Imaging Radiometer Suite (VIIRS) Chlorophyll-*a* prototype 2km resolution

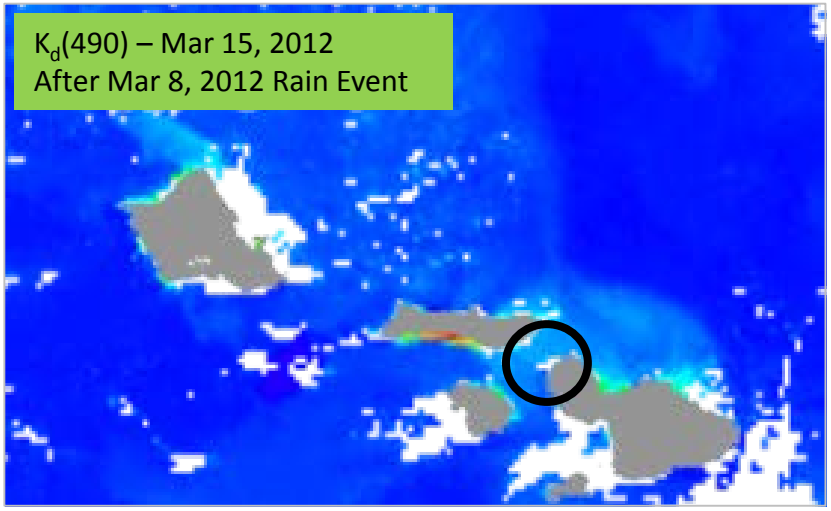


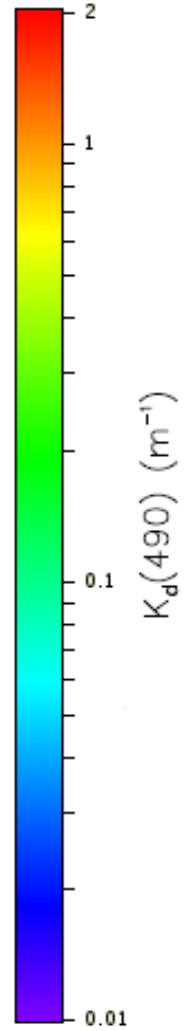
Visible Infrared Imaging Radiometer Suite (VIIRS) Chlorophyll-*a* prototype 750m resolution

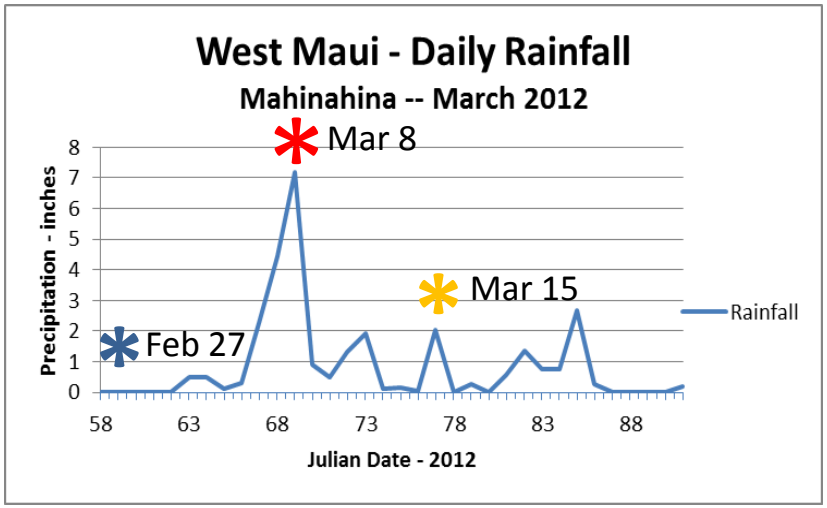


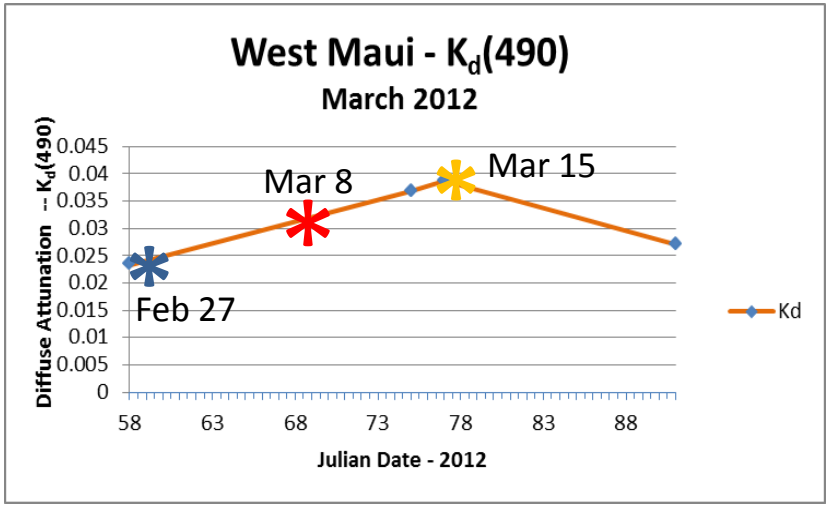
Proof of Concept
Matching with Precipitation Events





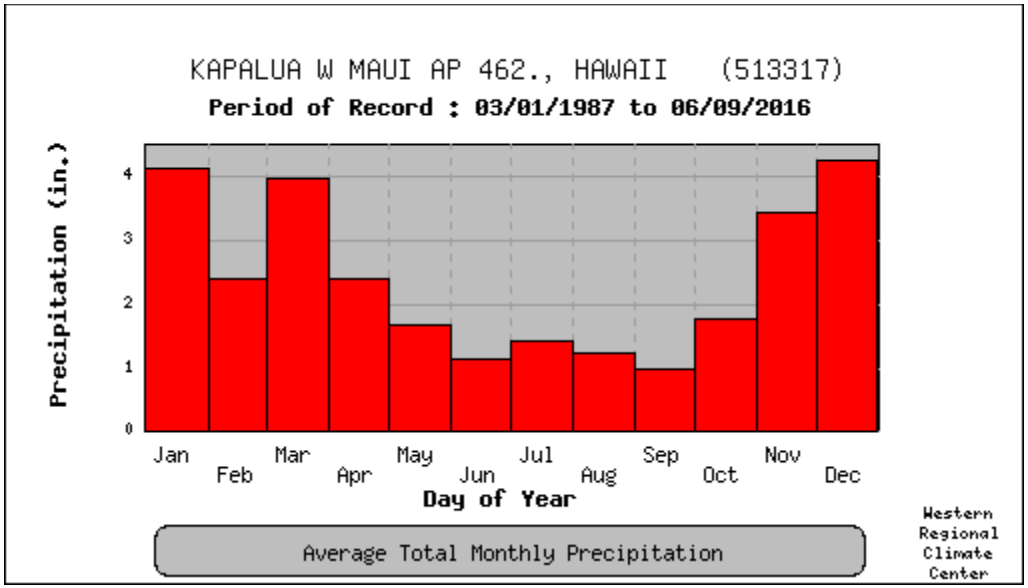




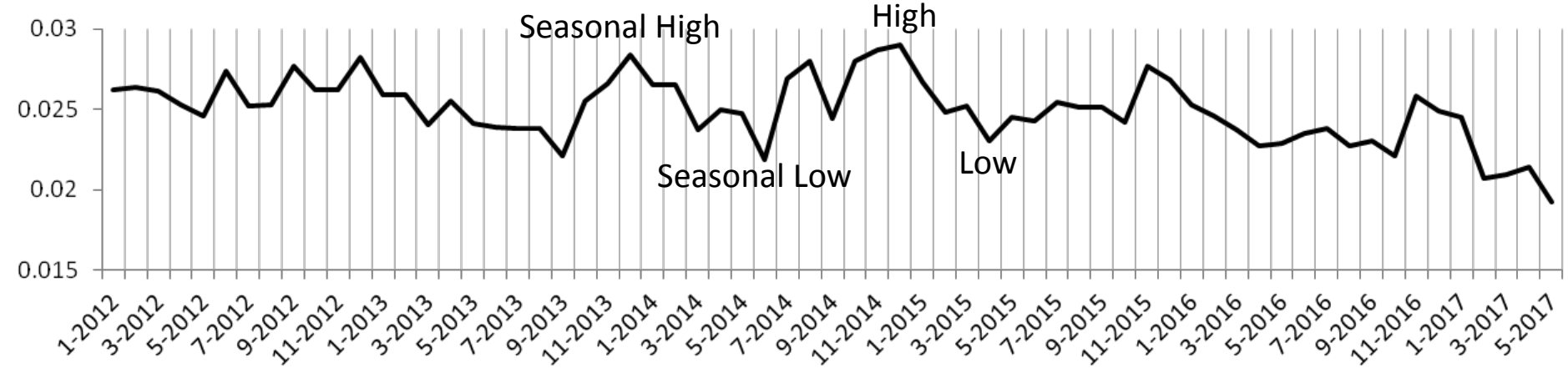


Top left and right: VIIRS K_d(490) images for February 27 and March 15, 2012. Black circles indicate the West Maui watershed. **Bottom left:** Daily rainfall amounts in Mahinahina from February 27 to March 31, 2012. **Bottom right:** K_d(490) values near West Maui watershed for the same time period. The large rainfall event is associated with a local rise in K_d(490) or turbidity.

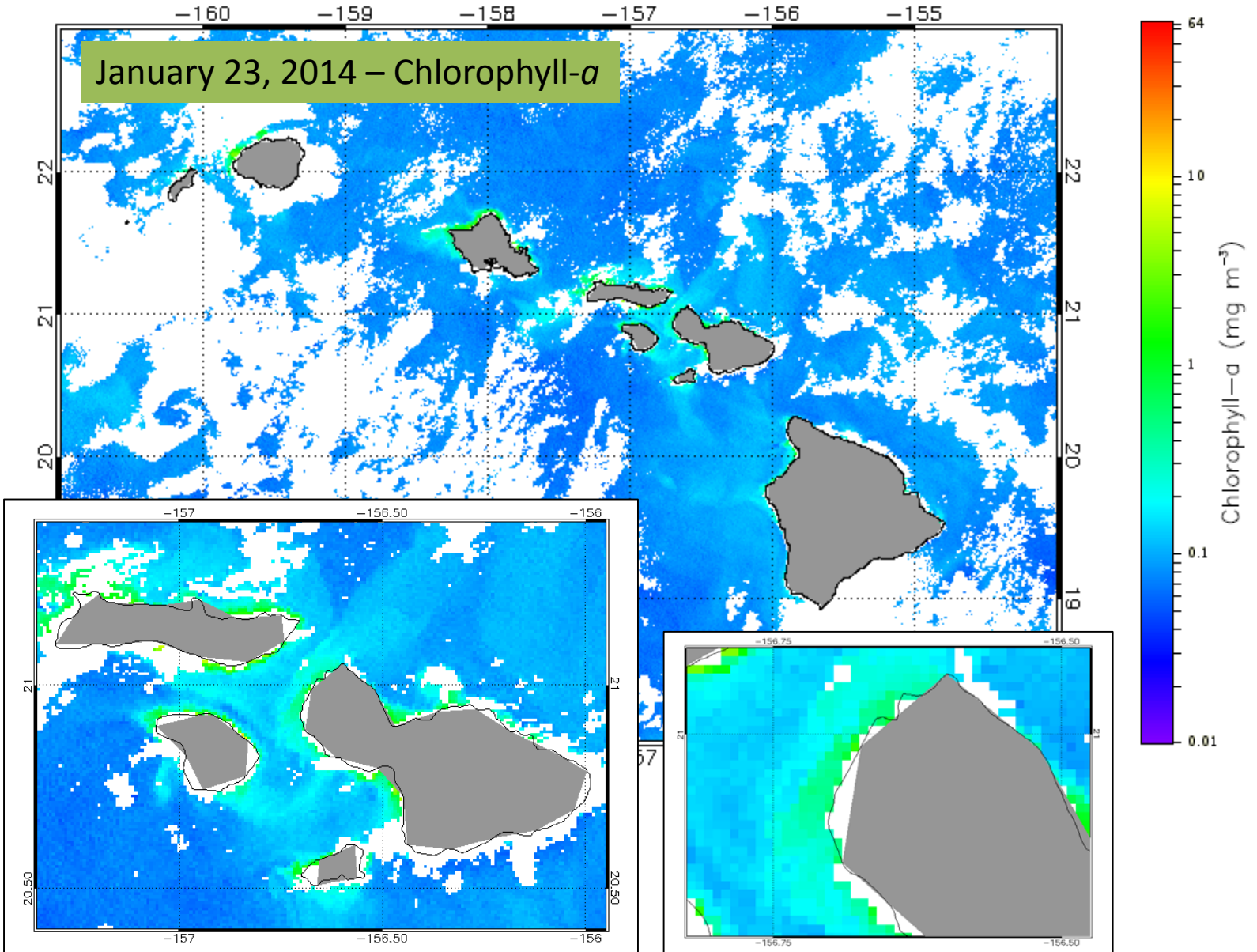




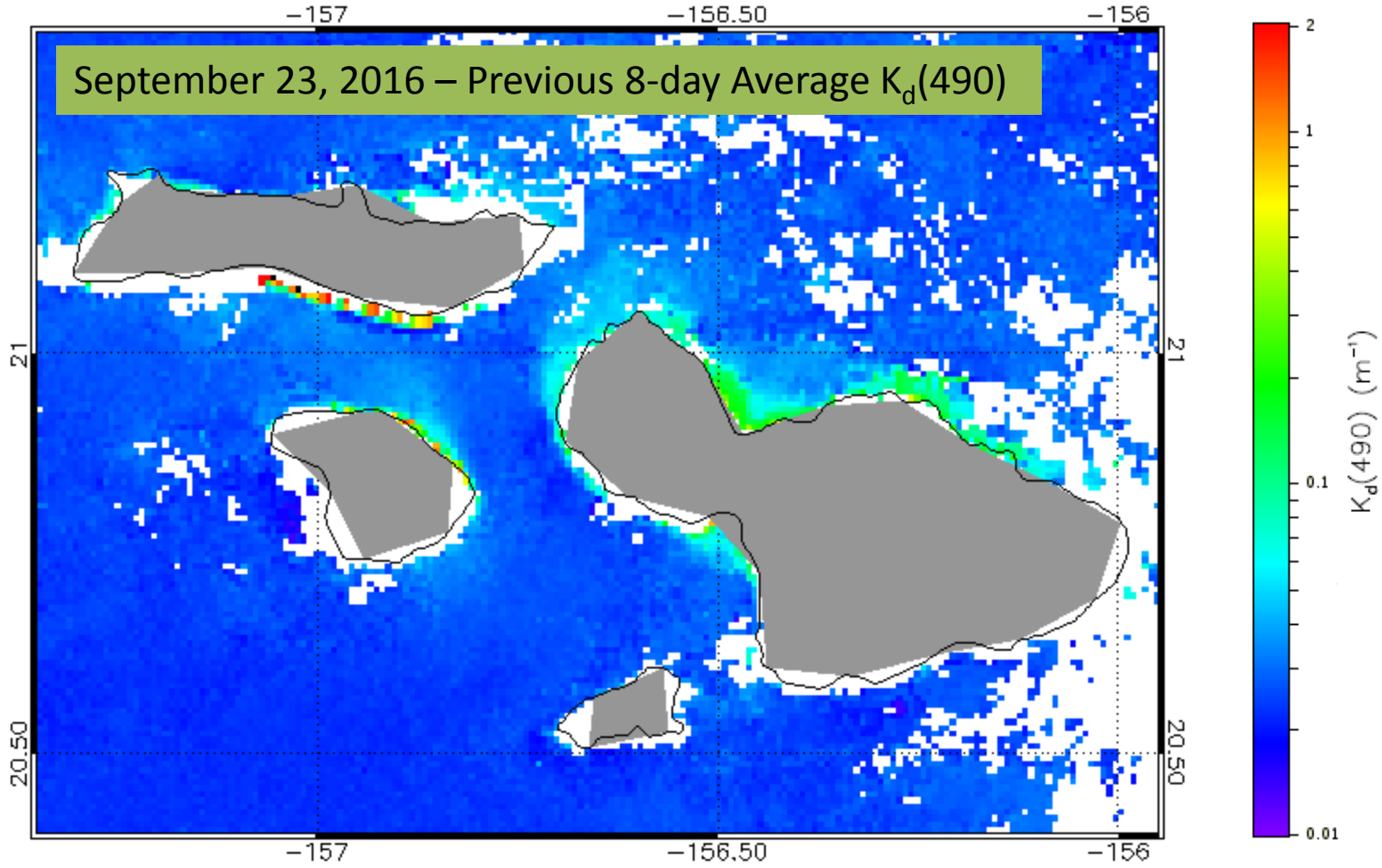
VIIRS Monthly Mean $K_d(490)$ for West Maui Region (2012 – mid 2017)



Coral Reef Watch Tools
Daily Mapped Ocean Color Images – 750m

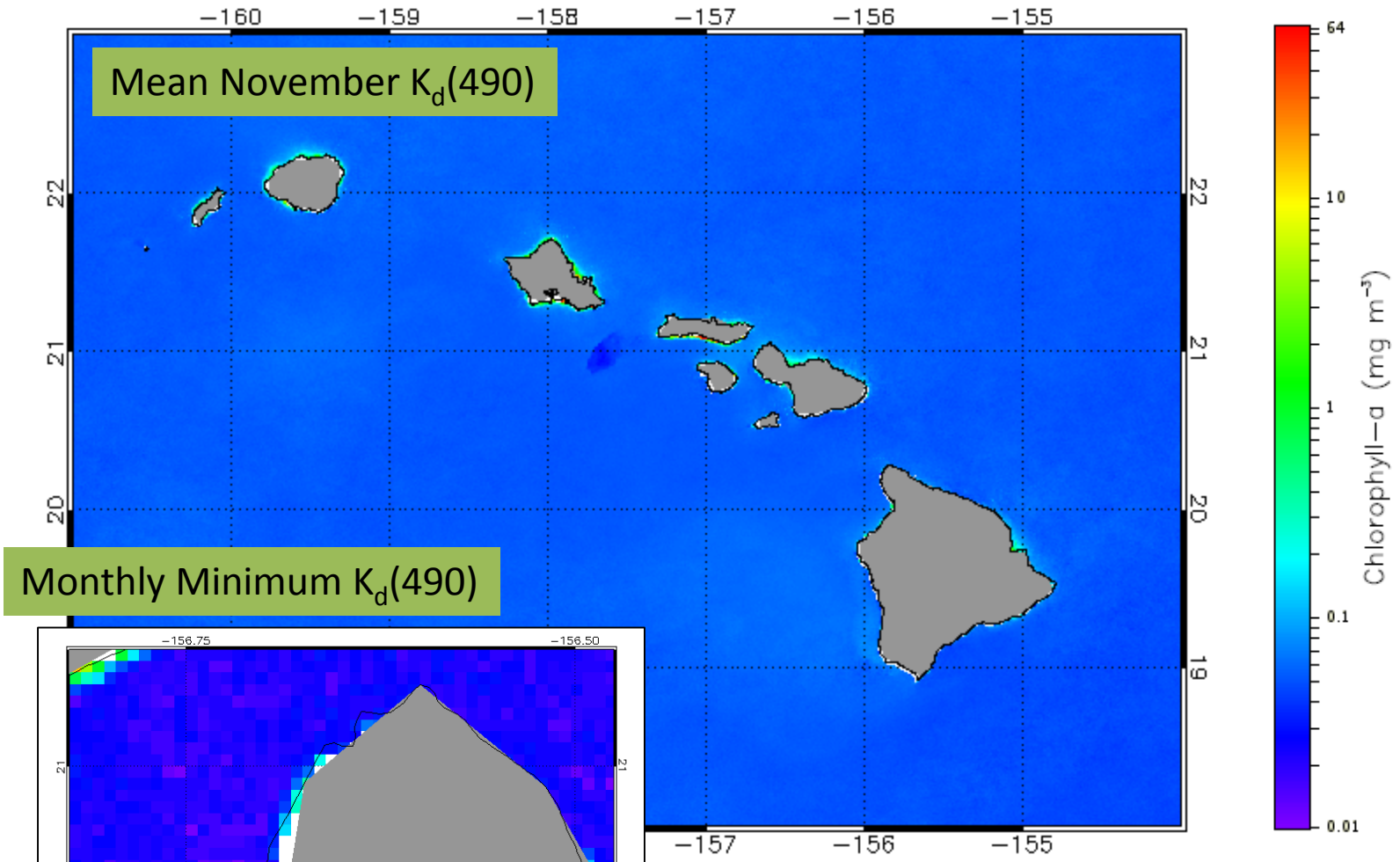


Coral Reef Watch Tools
3- and 8-Day Average Ocean Color Images – 750m

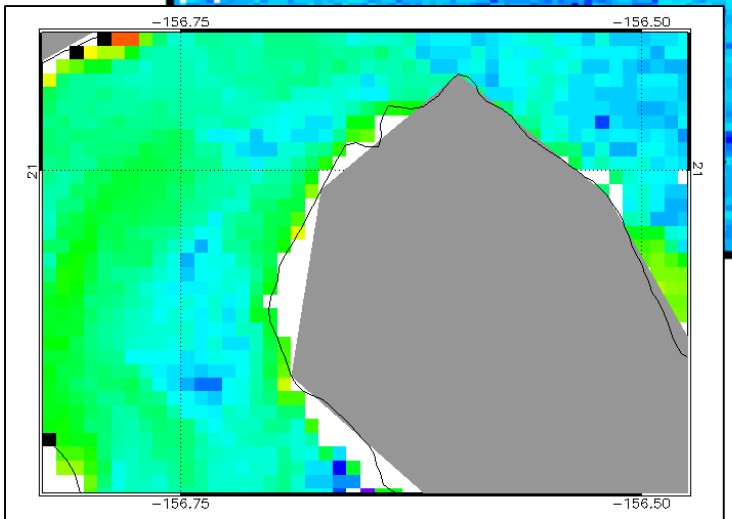


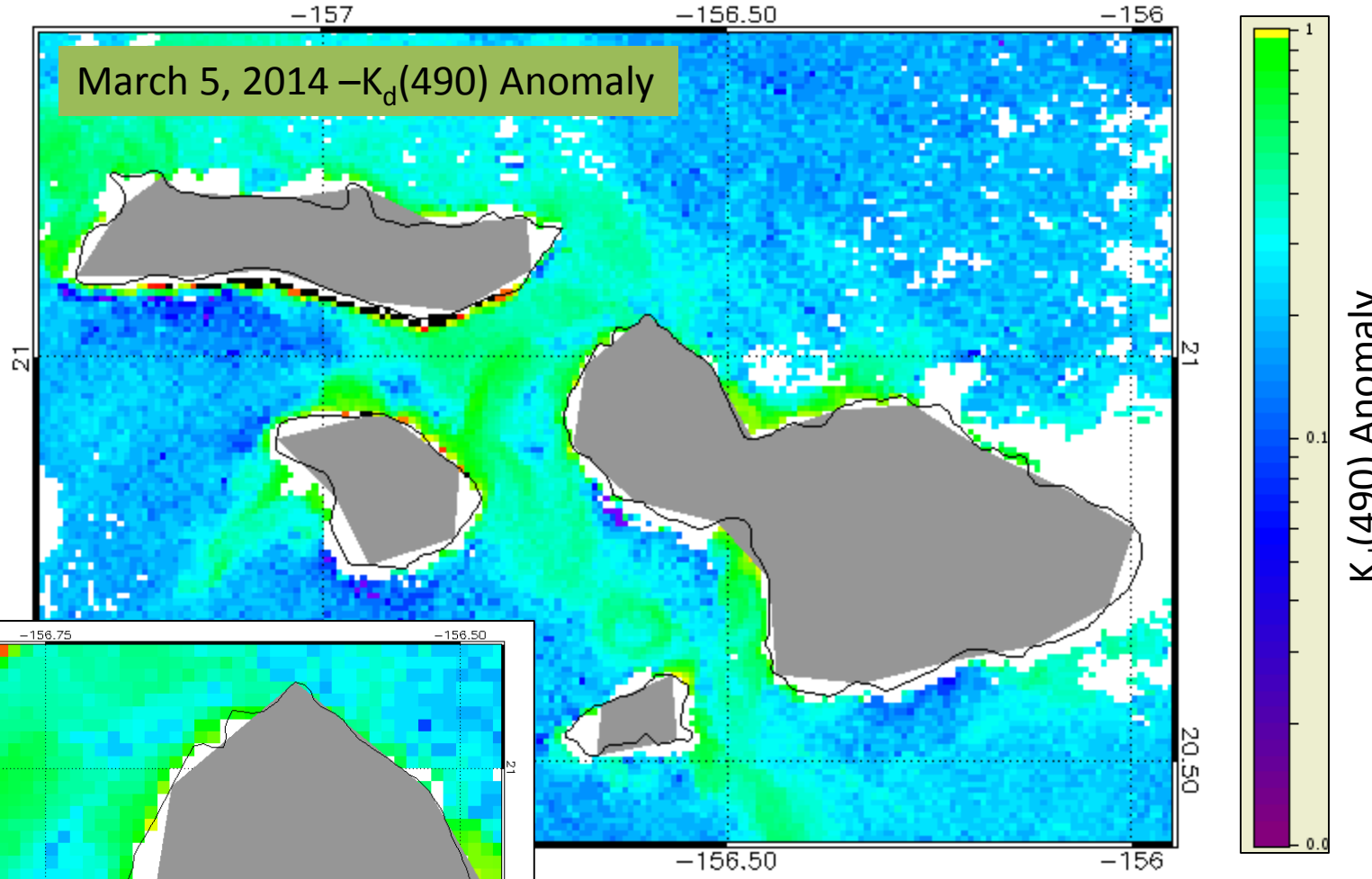
September 22-30, 2016: Brown water events captured by drones

Coral Reef Watch Tools
Climatological Means and Minimums



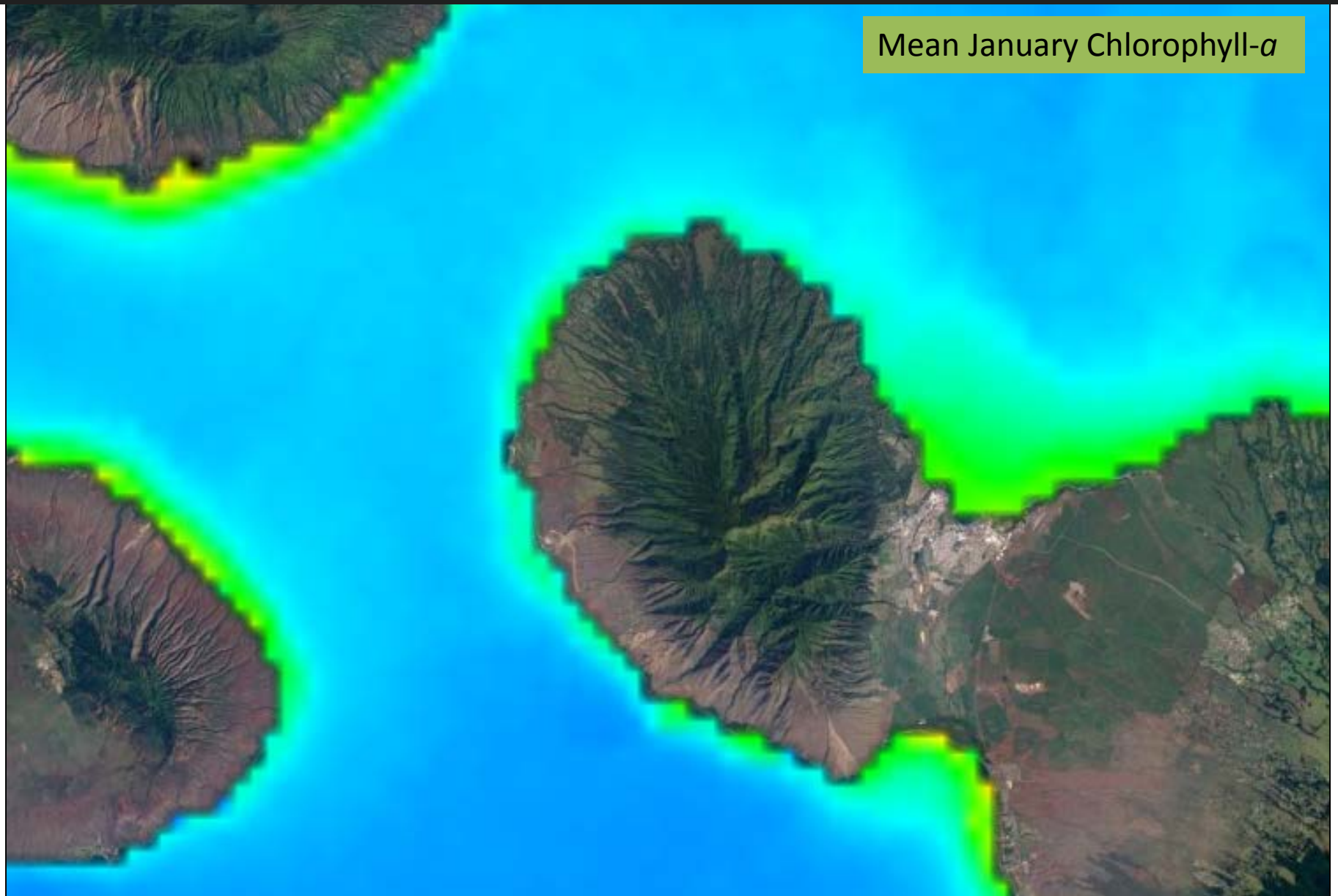
Coral Reef Watch Tools
Anomalies



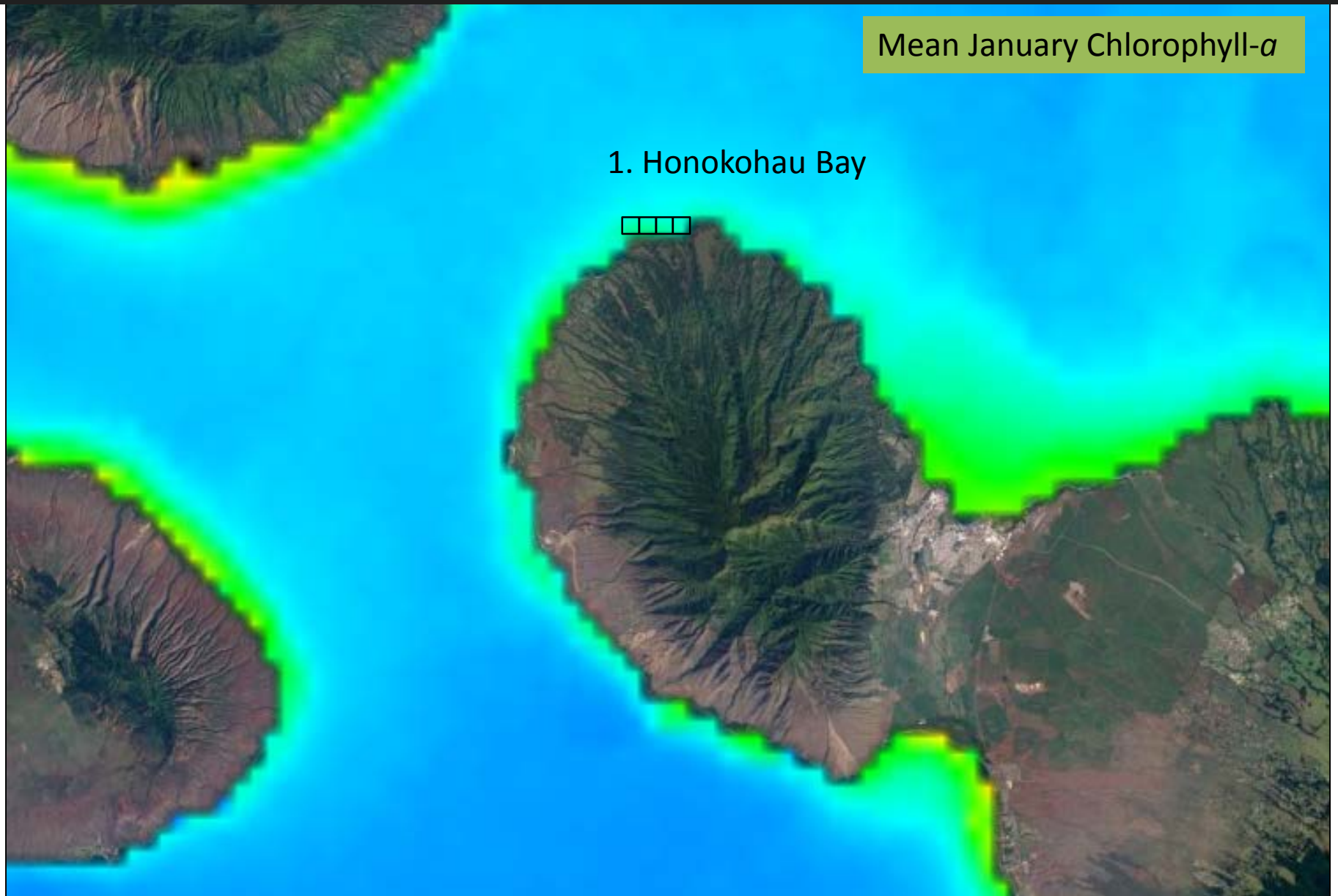


March, 2014: Large rainfall events

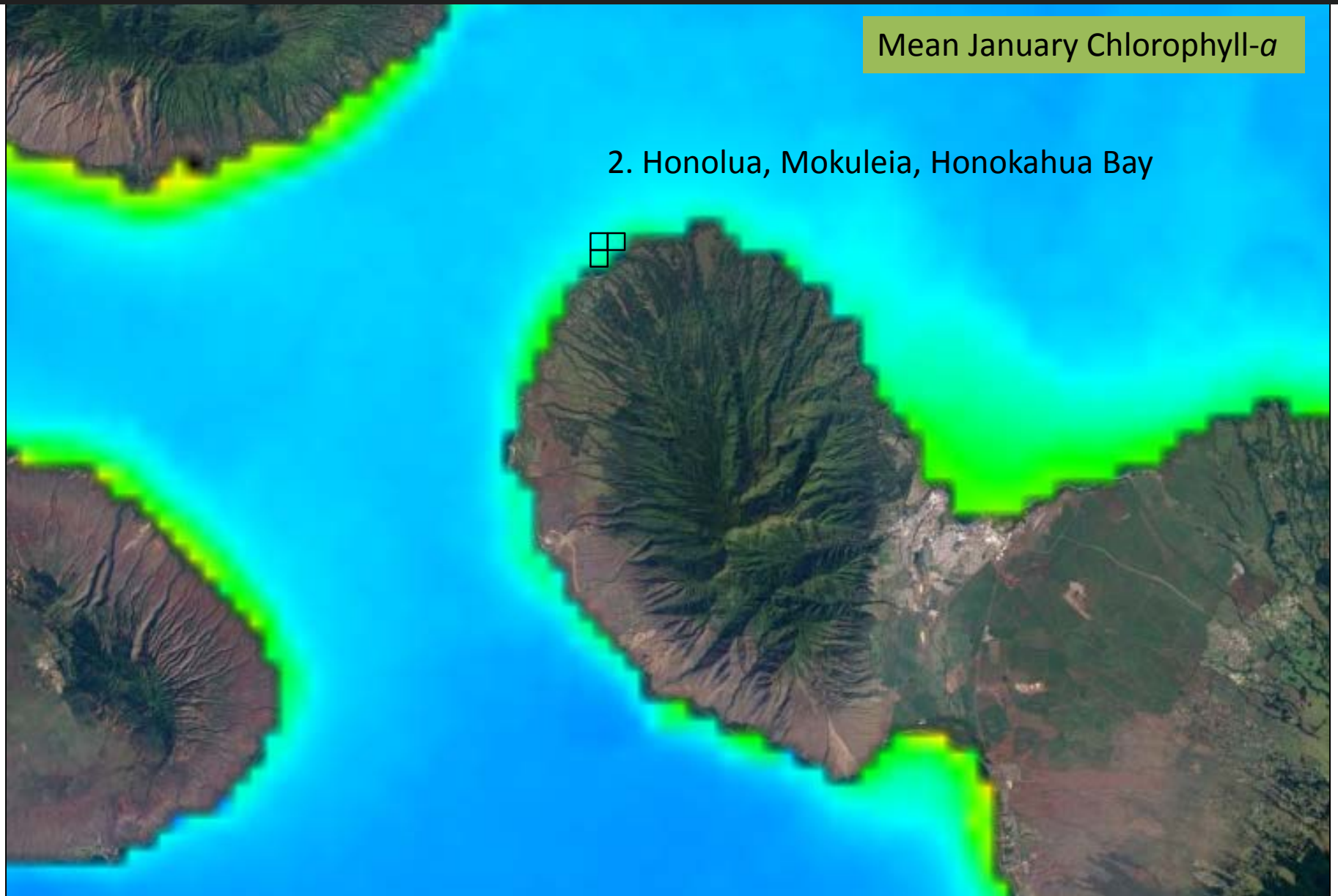
Coral Reef Watch Tools
Virtual Monitoring Areas



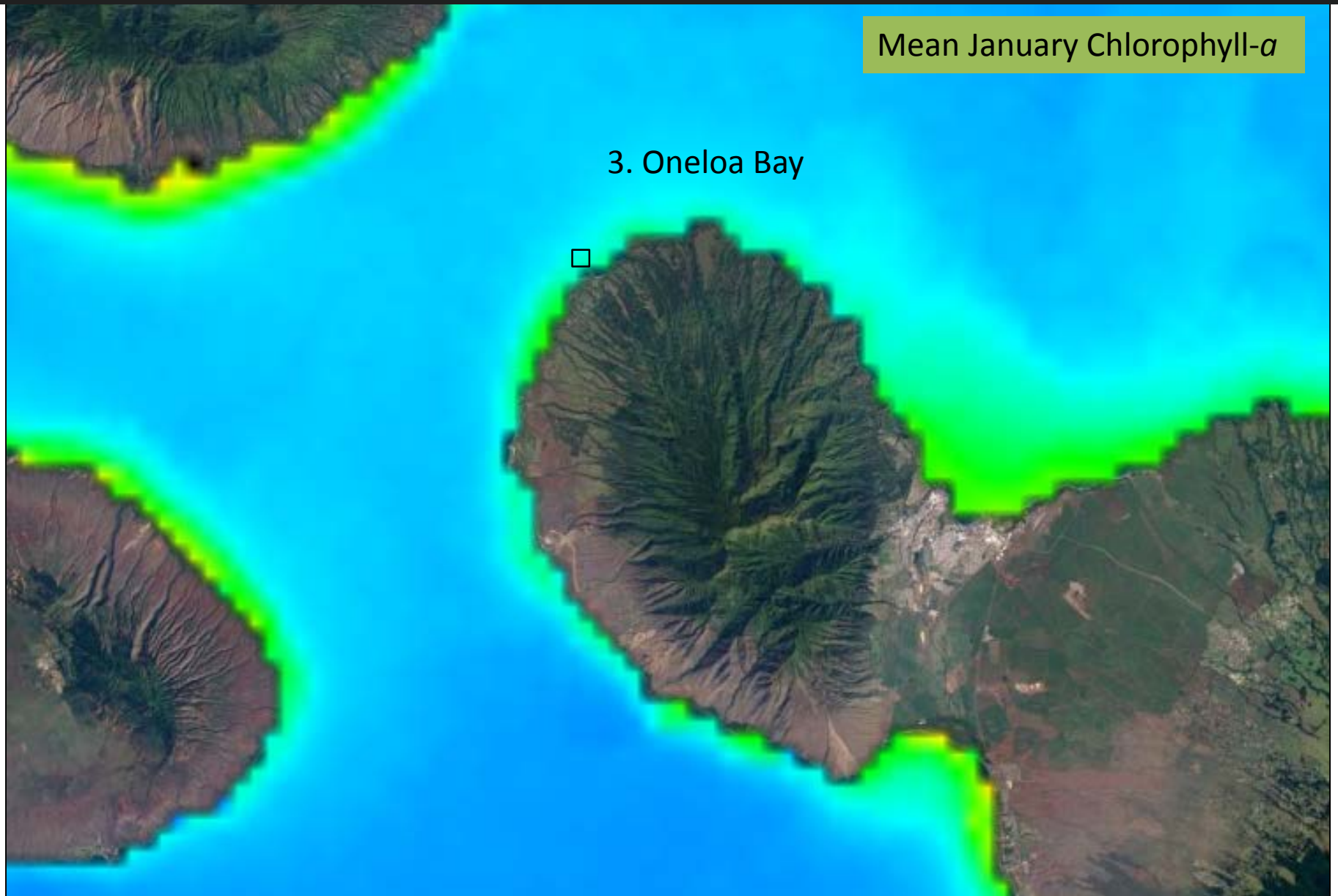
Coral Reef Watch Tools
Virtual Monitoring Areas



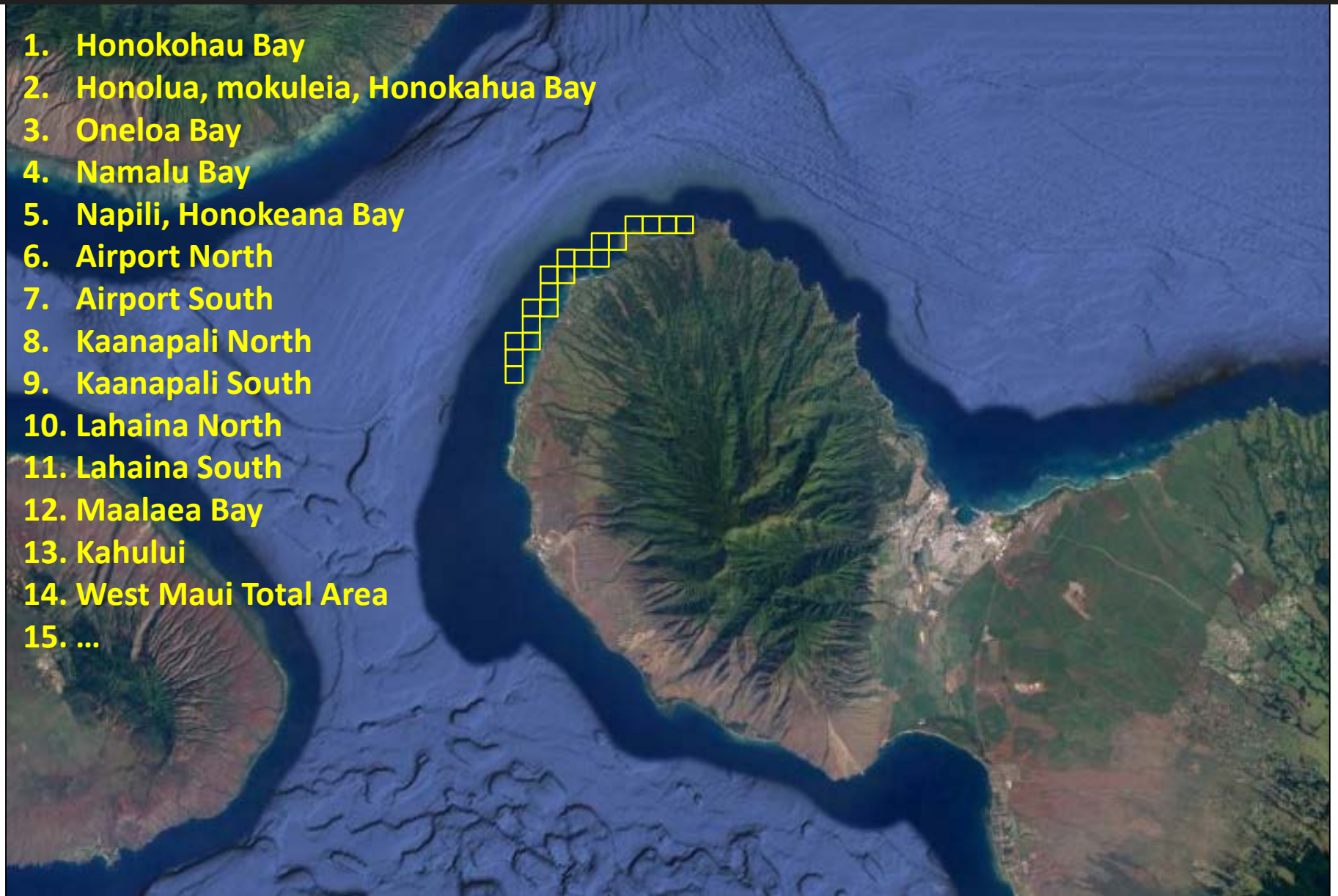
Coral Reef Watch Tools
Virtual Monitoring Areas



Coral Reef Watch Tools
Virtual Monitoring Areas

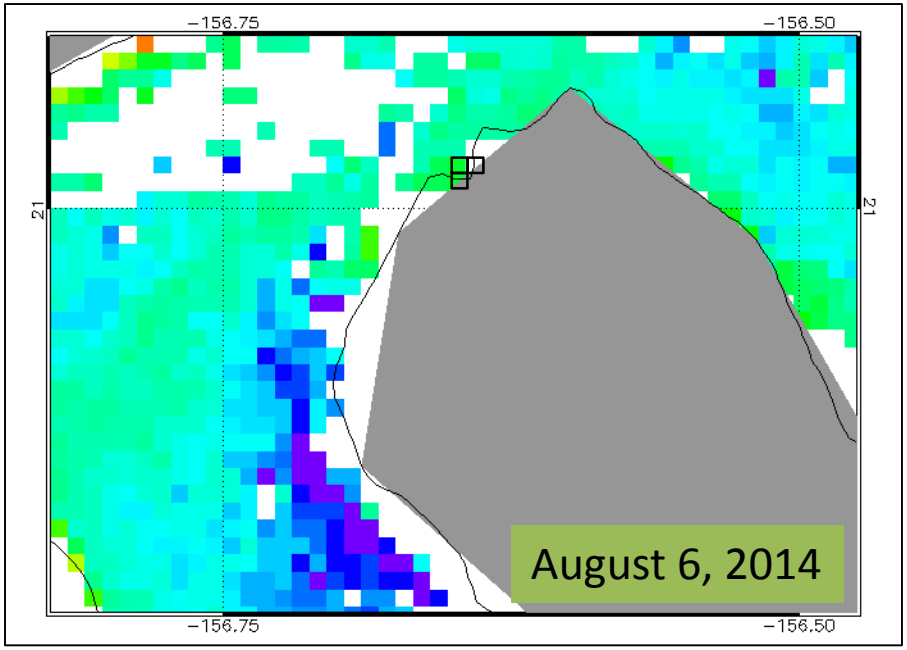


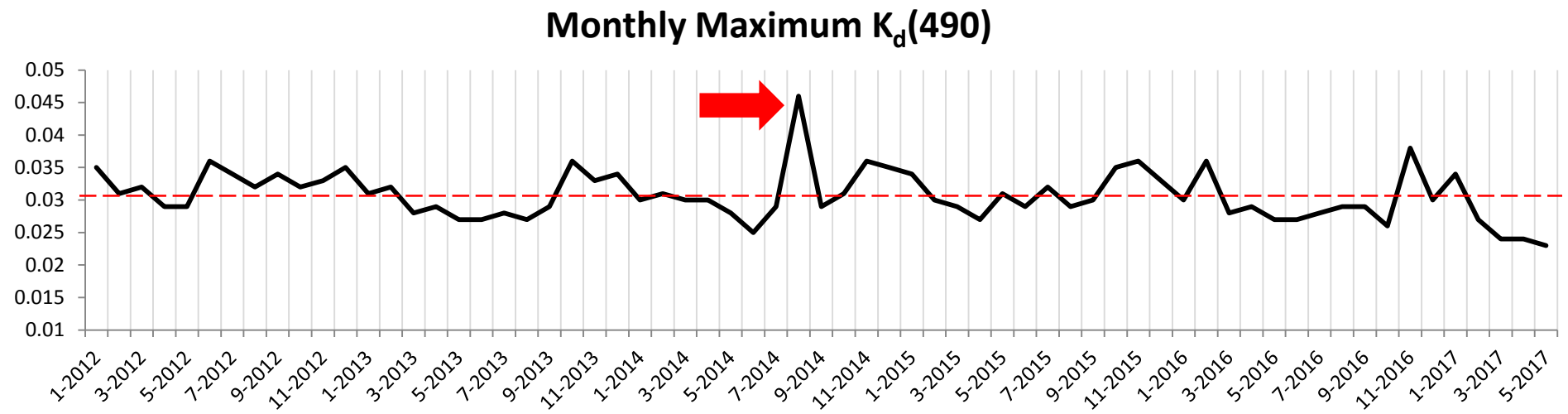
Coral Reef Watch Tools
Virtual Monitoring Areas



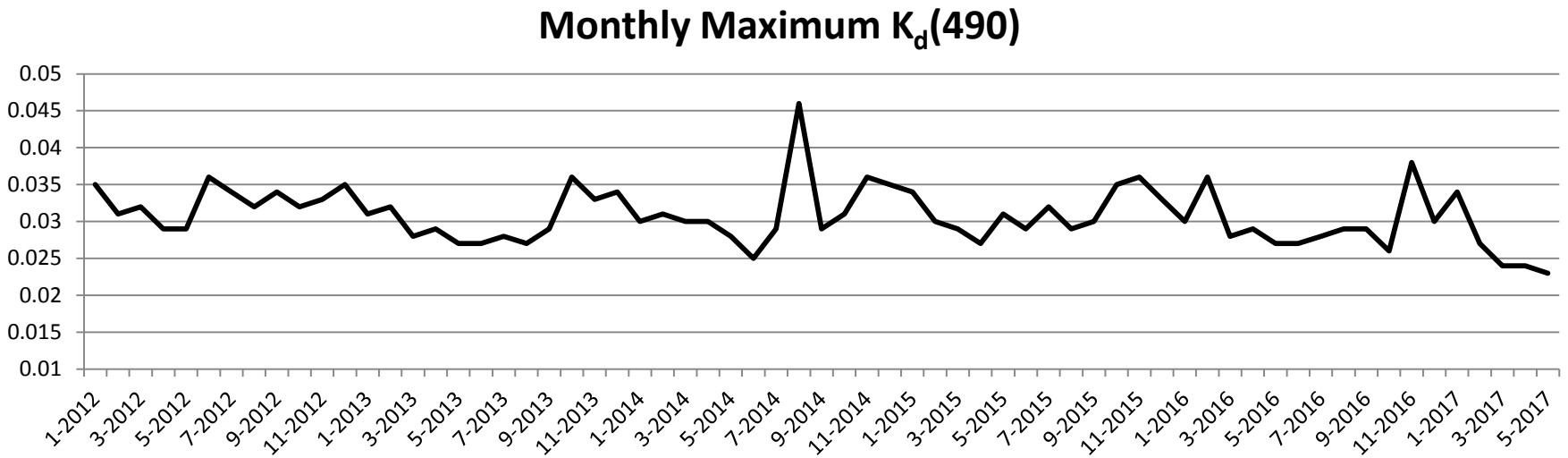
Coral Reef Watch Tools
Virtual Monitoring Areas

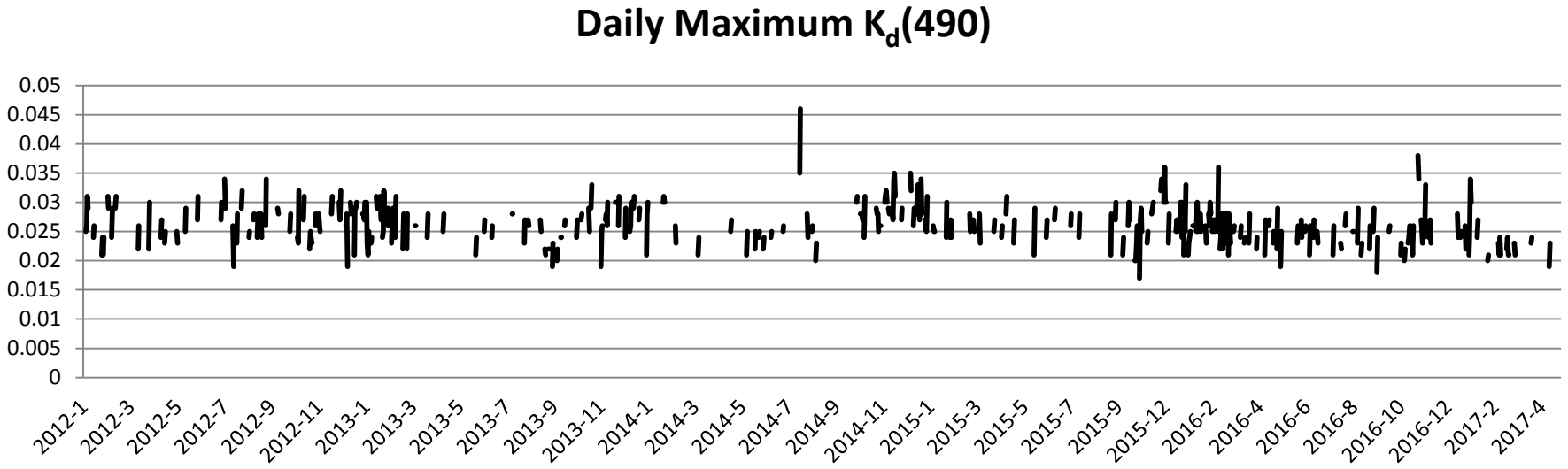




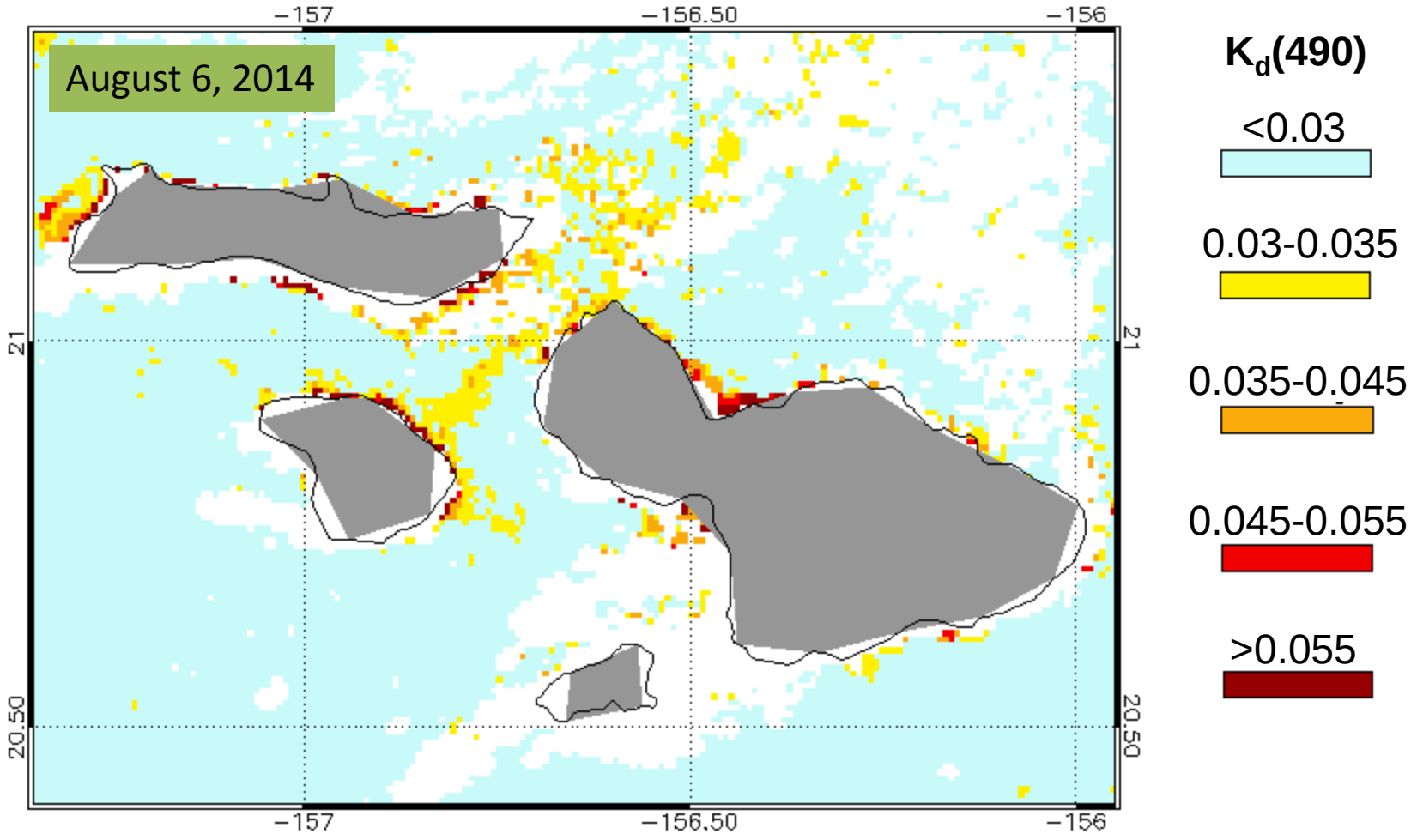


Coral Reef Watch Tools
Virtual Monitoring Areas

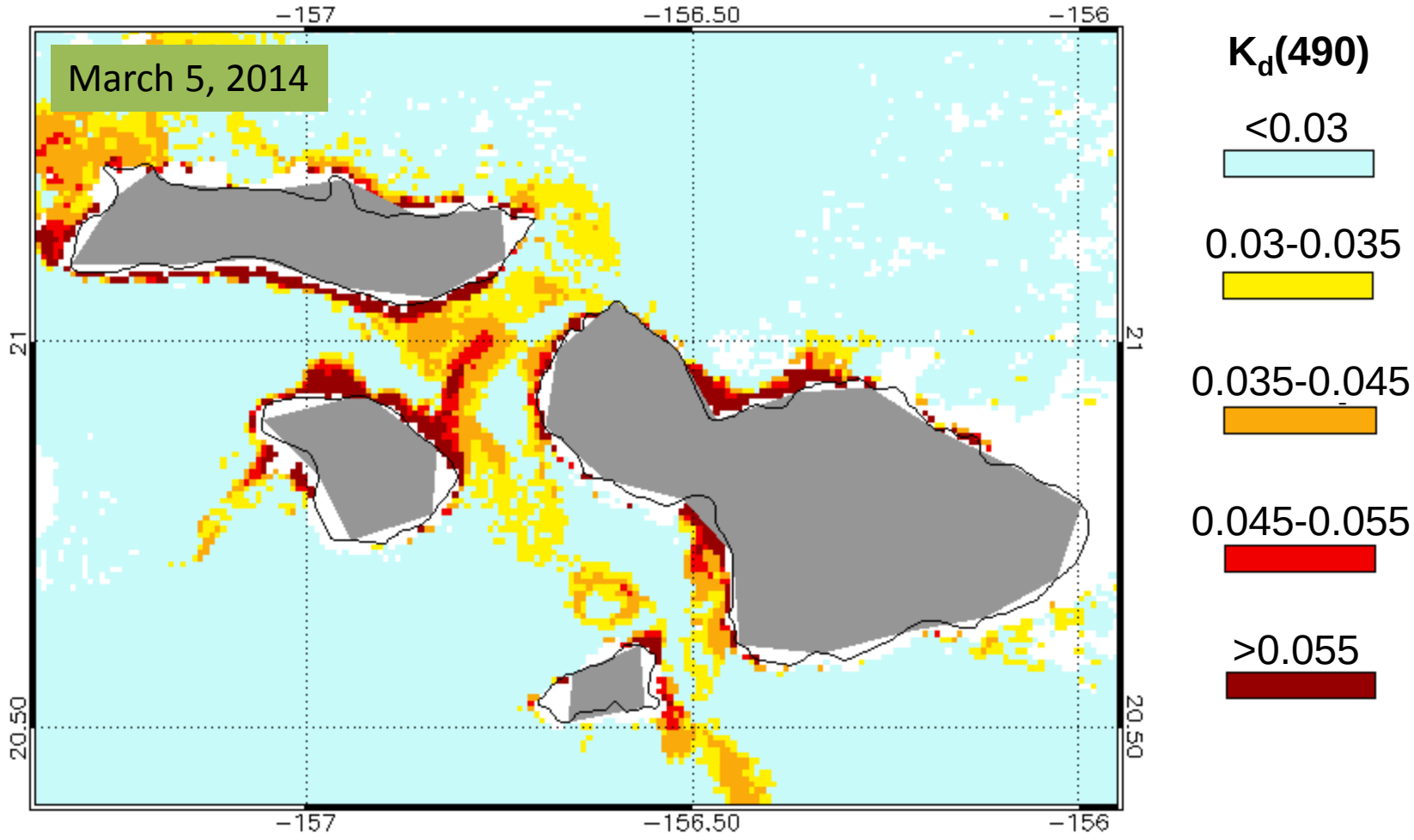




Coral Reef Watch Tools
Alert Products



Coral Reef Watch Tools
Alert Products



Coral Reef Watch Tools
Manager's Portal

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

DOC > NOAA > NESDIS > STAR > CRW

Coral Reef Watch

CRTF | CRCP | CREIOS | CoRIS



CRW Home

Product Overview

Near-Real-Time Data
- 5-km Resolution
- 50-km Resolution

Experimental Products

Research Activities
- Bleaching Obs Reporting
- Ocean Color
- Projections: OA/Bleaching
- Projections: Bleaching 4km
- Ocean Acidification
- Hydrodynamic Modeling
- Paleoclimatology
- High-resolution SST
- Decision Support System
- QCed Bleaching Obs

Outreach/Education

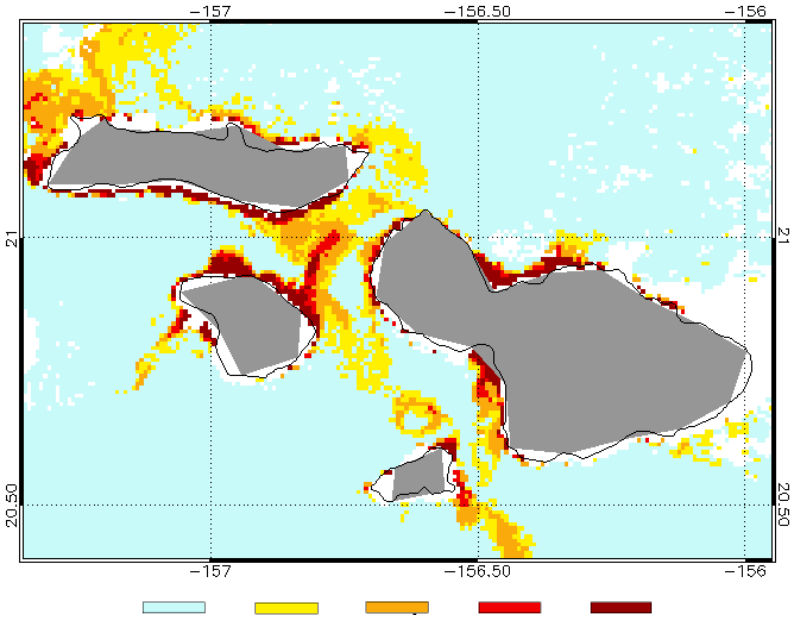
Research Partnerships

Publication List
- Cite CRW Data & Products

Report Bleaching

West Maui Ocean Color Monitoring

Product: Chl-*a* | K_d(490) | Anomaly | **Alert**



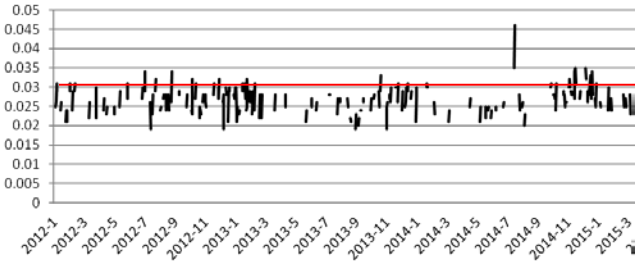
Map Extent: ▼ Maui

Aggregation: ▼ Daily

Virtual Area: ▼ Namalu Bay

Time Series: ▼ Max k_d(490)

Daily Maximum K_d(490)



High Resolution True Color: **Sentinel-2** | Landsat



Local Ocean Color in ArcGIS Web Map

- Proposed information platform using GIS for HI and PR.
- Information can be compiled in a web mapping application for watershed managers that can include:
  - Watershed layers
  - Benthic habitat/land cover maps.
  - Water quality from satellites (VIIRS, Landsat/Sentinel).
  - *In situ* water samples results.
  - Layers from watershed managers.

UPRM Sample



http://arcg.is/1QpyIL7

coralreefwatch.noaa.gov/satellite/research/oceancolor

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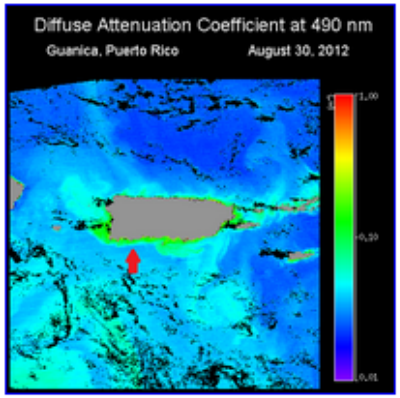
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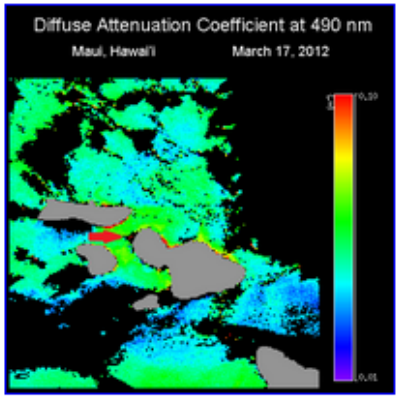
Outreach/Education

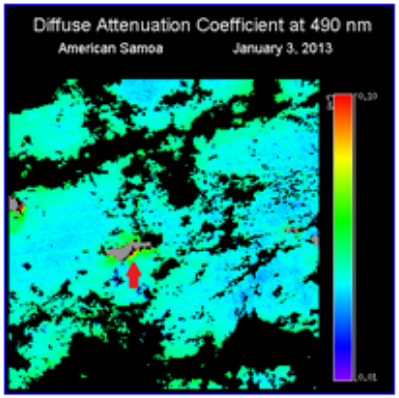
Research Partnerships

Publication List
- Cite CRW Data & Products

Satellite Ocean Color Product Development







Preliminary Results (event-driven variations in $K_d(490)$ and Chl-*a*):

- Click here for preliminary time series results for Puerto Rico.
- Click here for preliminary time series results for West Maui.

Presentations:

- Click here for a poster presented at the 2015 NOAA Satellite Conference.
- Click here for a poster presented at the 2016 Ocean Sciences Meeting in New Orleans.

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 NOAA Joint Polar Satellite System (JPSS).

The pilot satellite ocean color products are designed to help coral reef ecosystem managers monitor variable water

University of Hawaii – Maui College
Professor Brown's Student Exploratory Team



Bio-Optical Oceanography Laboratory Team Members

- Dr. Roy Armstrong -Director
- Dr. Yasmin Detres - Researcher
- Suhey Ortiz, Maria Cardona, Myrna Santiago, Jenniffer Perez, Omar Lopez -Graduate Students
- Luis Lugo - Staff





Thank you from the NOAA Coral Reef Watch Team!!



Mark Eakin



Jacquie De La Cour (GST)



Gang Liu (GST)



Erick Geiger (GST)



Ben Marsh
(GST & ReefSense)



Kyle Tirak (GST)



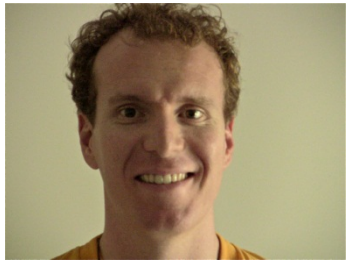
Andrea Gomez
(CCNY & NOAA-CREST)



William Hernandez Lopez
(CCNY & NOAA-CREST)



William Skirving
(GST & ReefSense)



Scott Heron (GST & ReefSense)



Rob Warner (NOAA/NOS)



Al Strong (GST & SR)

NESDIS
National Environmental Satellite, Data and Information Service

NOAA NESDIS STAR
Center for Satellite Applications and Research
SMC CORP SOC

NOAA CORAL REEF CONSERVATION PROGRAM

GLOBAL SCIENCE & TECHNOLOGY, INC.





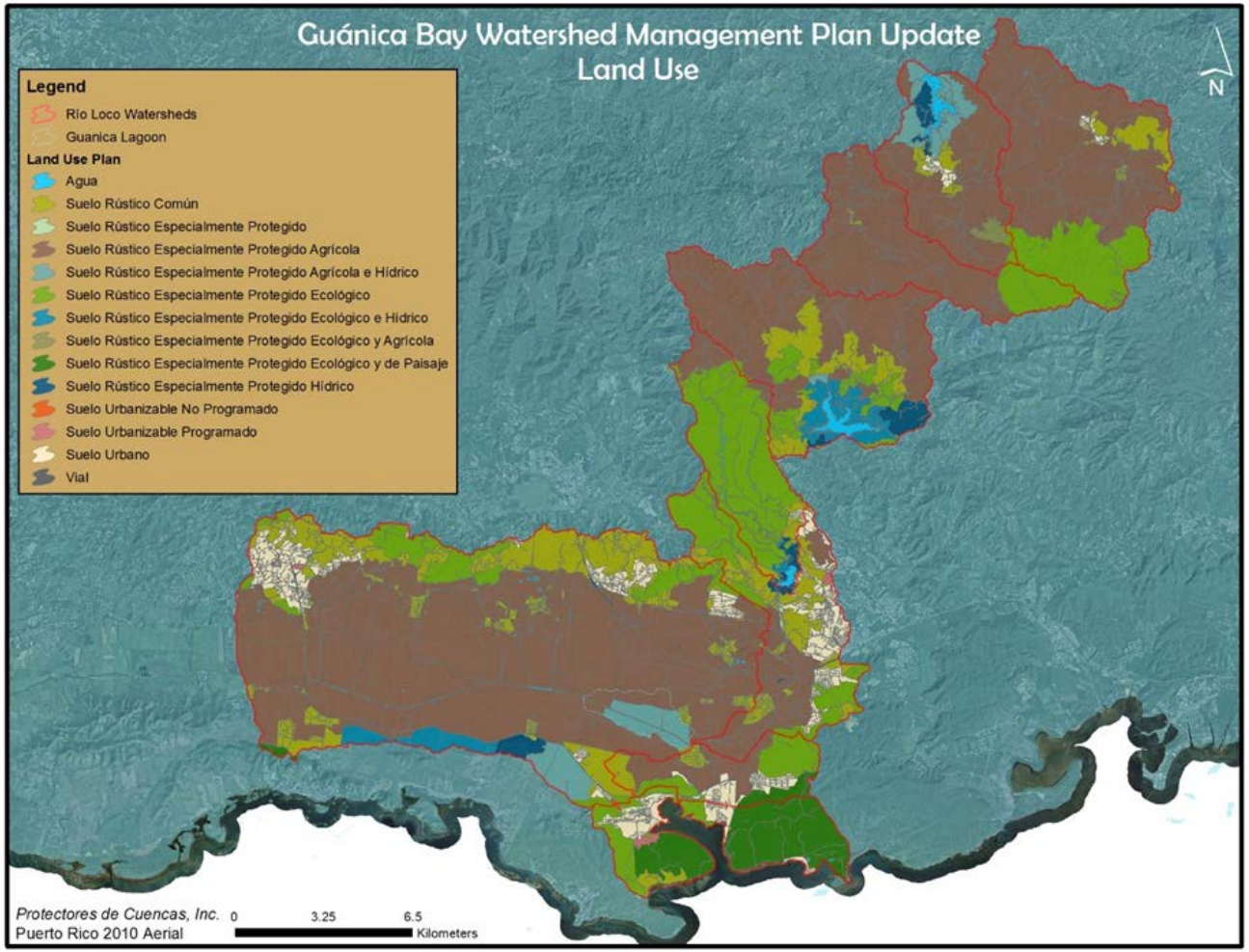
The Watershed Perspective on Ocean Color: Possible Application and Needs in Puerto Rico

Paul Sturm
Ridge to Reefs
Roberto Viqueira Ríos
Protectores de Cuencas
Guánica Watershed Coordinator

STAR JPSS Meeting
Annual Science Team Meeting
August, 2017

The Guanica Bay Watershed Management Plan:
A Pilot Project for Watershed Planning in Puerto Rico

- The ***Guanica Bay Watershed Management Plan*** was Completed in 2008.
- Coordination Efforts 2010-Present
- Implementation 2012-Present
- Update 2015-Present



UPDATE:

- Address the EPA's nine elements of a watershed management plan
- To date, 65% of the updated document has been drafted.
- Updating a watershed characterization based on new develop land use information provided by the Puerto Rico Planning Board (2015)
- Updates from the restoration activities that has been developed.
- Update estimated pollutant louds applying the Watershed Treatment Model.
- Final updated draft of the Plan is expected to be completed by August of 2017.

Guánica Lagoon

- From 2010-2013 major improvements had been achieved.
  - Strong Commitment from the Puerto Rico Government in General
  - Soil Salinity Study
  - H & H Study
  - Farm Inventory
  - Socioeconomic Study
  - 65% engineering Design
  - Enviromental compliance
- An important drawback in the restoration efforts raised (2013)
  - Intentions of the DA to regain farming activities inside the historic footprint of the Guanica Lagoon.
  - PRLA started clearing wetland areas for farming without any environmental compliance process and public engagement.
  - Most of our efforts where dedicated to protect the Lagoon
  - Legal action was taken with the USACE and EPA
- PRLA was fined and a precedent was established for wetland protection
- No clearings for the past 3 years
- Current Administration stepping back
- NRCS has approved funding to implement conservation practices in the subwatershed of the Lajas Valley.



Next Steps:

- A series of meetings are being coordinated that will take place in the following months with new Government officials to present the project and gain support from the new Government administration.
- Another set of meetings will be coordinated with the farming community to ensure their participation in the process and to reopen the possibility of an agreement of the difference in public policy towards the land in the Lagoon area.
- An outreach and education campaign

Río Loco River Restoration

- NRCS implementation of 3 major restoration projects on the Río Loco river to restore river banks with bioengineering strategies that included the implementation of a collaborative effort to apply hydroseeding on the restored areas by Protectores de Cuencas, Inc.
- During this process, most of the old abandoned irrigation infrastructure inside the river that was identified in the Watershed Management Plan as priority to be removed were taken out of the river.
- 2 sites remaining that we have secure funding from the DNER to remove them in the following year

Next Steps:

- Currently working on Enviromental Compliance
- Debris removal for next year







GUÁNICA TREATMENT WETLANDS

- 100% engineering designed
- 100% of permit process completed
- Close to final MOU with PRASA
- NPDS Permit Issue Resolved

Next Steps:

- Coordinate with community and Municipality
- Start Construction

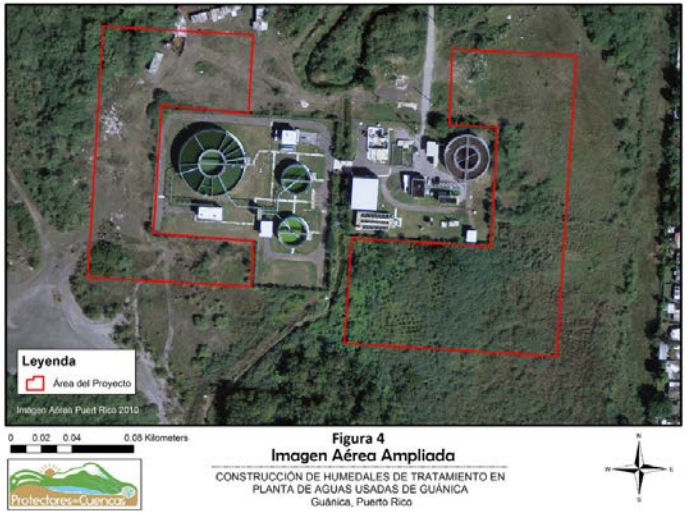
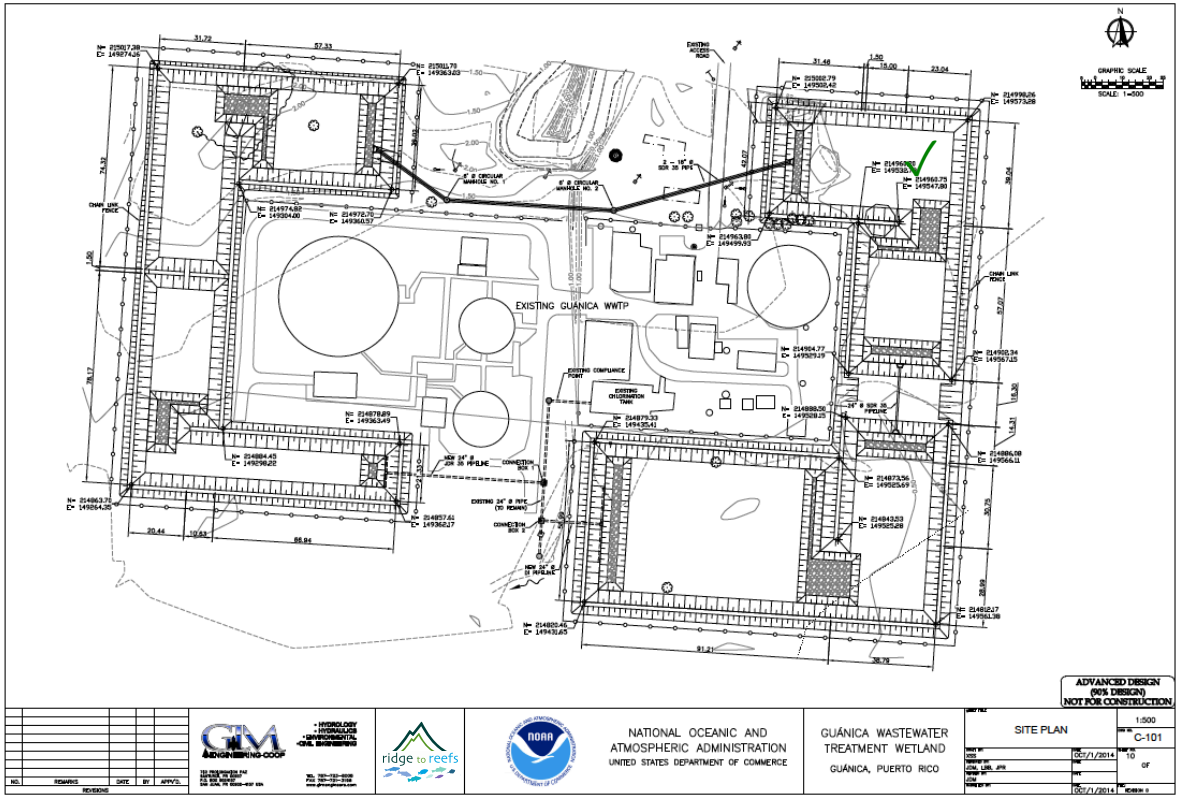


Figura 4
Imagen Aérea Ampliada
CONSTRUCCIÓN DE HUMEDALES DE TRATAMIENTO EN PLANTA DE AGUAS USADAS DE GUÁNICA
Guánica, Puerto Rico



REDUCING SEDIMENT TRANSPORT/ UPPER AREA

Shade Coffee Roundtable Initiative

- Instigated by Protectores de Cuencas in March 2011.
- Farmers, Academia, NGO's, State and Federal Agencies.
- To develop criteria for shade coffee certification for Puerto Rico
- Identify incentives for motivating coffee producers to continue to use historical agricultural practices that are sustainable and environmentally friendly
- Help create economic niches for the coffee produced in the shade that can be marketed separately and that results in greater profits for producers.
- Continue working towards the institutionalization of these practices and programs
- PDC identified and enrolled 10 farmers interested in obtaining the shade coffee certification.

Next Steps:

- Finalize Certification Process.
- Foundation of a Certification Entity.
- Certify 10 farmers and include Certification Logo in 3 Coffee Brands.









Expanding Conservation/Sediment Control Practices

- Implementation of Hydroseeding Techniques
- Collaboration on a sedimentation assessment Dr. Ramos.
- 95% of sediments come out from dirt roads in coffee farms
- NOAA Domestic Grant
- 3 Farms engaged
- 8 Different BMP implemented, tested and evaluated for effectiveness
- New Proposal submitted to expand Efforts to Sea Grant Program

Next Steps:

- New Proposals submitted to expand Efforts to NFWF and NRCS
- Certified conservation practices on NRCS programs

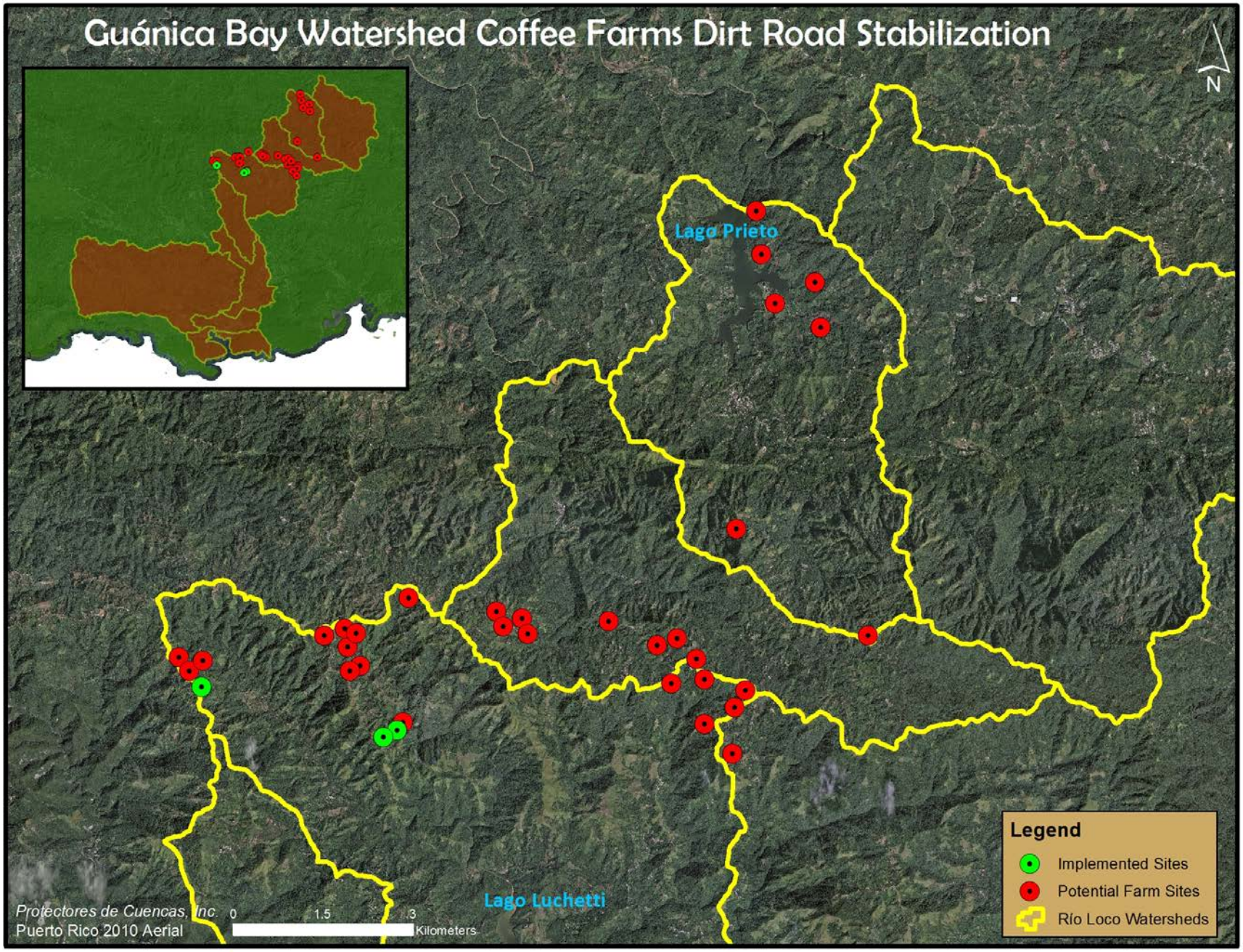











Guánica Bay Watershed Coffee Farms Dirt Road Stabilization
N
Lago Prieto
Lago Luchetti
Legend
Implemented Sites
Potential Farm Sites
Río Loco Watersheds
Protectores de Cuencas, Inc.
Puerto Rico 2010 Aerial
0
1.5
3
Kilometers

Source Area Pollution

Pollution Tracking IDDE

- Proposal to NFWF for IDDE and Demonstrative Project in the Río Loco Main Tributaries
- First round in pollution targeting

Next Steps:

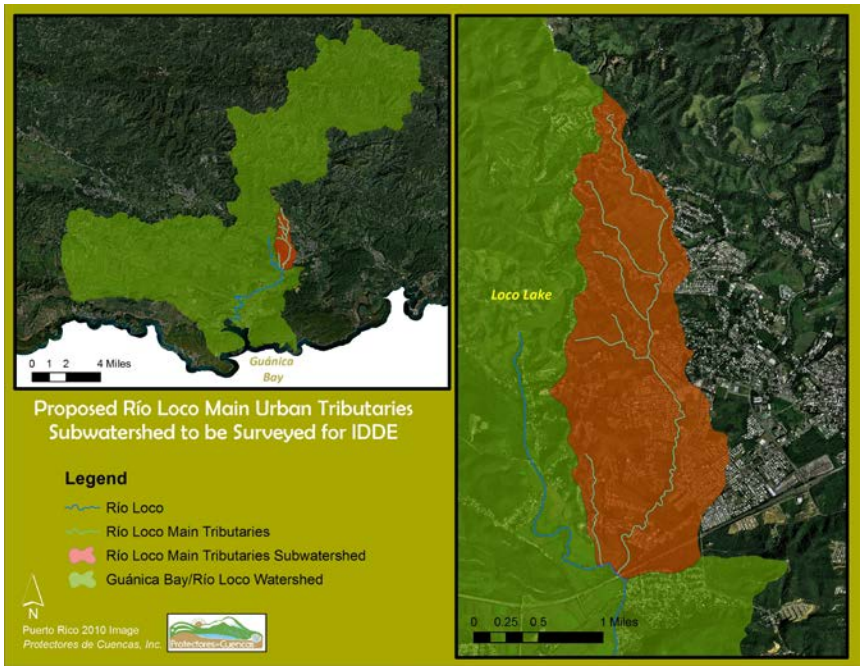
- Data analysis and projection
- Next round of samplings
- Submit Interim report
- Design of Pilot SWP project
- Implement Demonstrative project
- Conduct Additional EDDE in other areas of the coastal communities in Guánica
- Meeting and field visit with EPA and PRASA

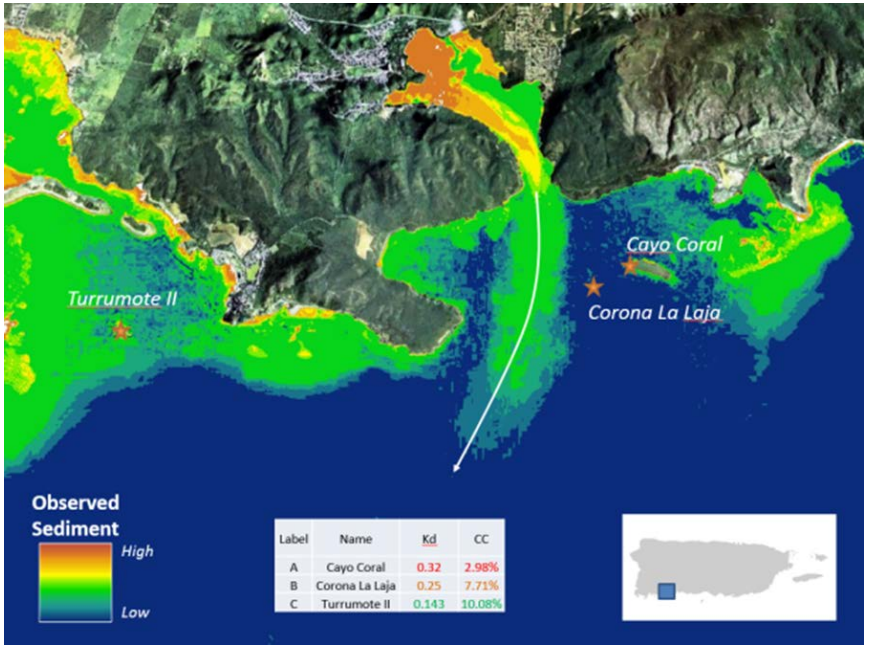
Monitoring

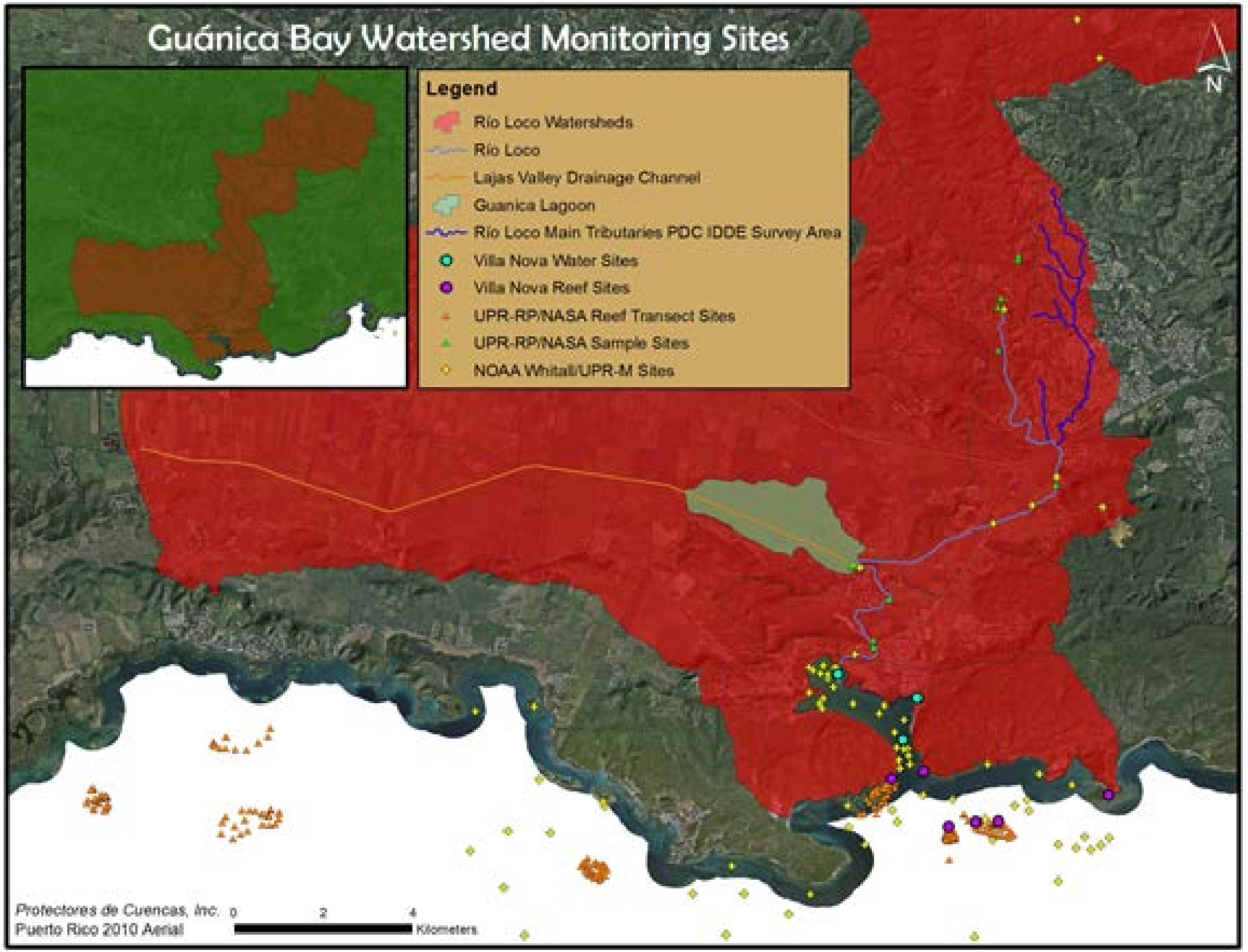
- Meeting with all partners conducting Monitoring
- Identification of Monitoring sites
- Proposal submitted to NOAA Domestic (UPR and NASA) for Baseline Remote Sensing Water Quality Assessment and characterization
- Proposal submitted to Sea Grant to continue with NASA monitoring.

Next Steps:

- Identify additional funding sources to continue monitoring
- Monitor Implementation SWP project in Malecón area






Guánica Bay Watershed Monitoring Sites
Legend
Río Loco Watersheds
Río Loco
Lajas Valley Drainage Channel
Guanica Lagoon
Río Loco Main Tributaries PDC IDDE Survey Area
Villa Nova Water Sites
Villa Nova Reef Sites
UPR-RP/NASA Reef Transect Sites
UPR-RP/NASA Sample Sites
NOAA Whitall/UPR-M Sites
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Protectores de Cuencas, Inc.
Puerto Rico 2010 Aerial
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2
4
Kilometers

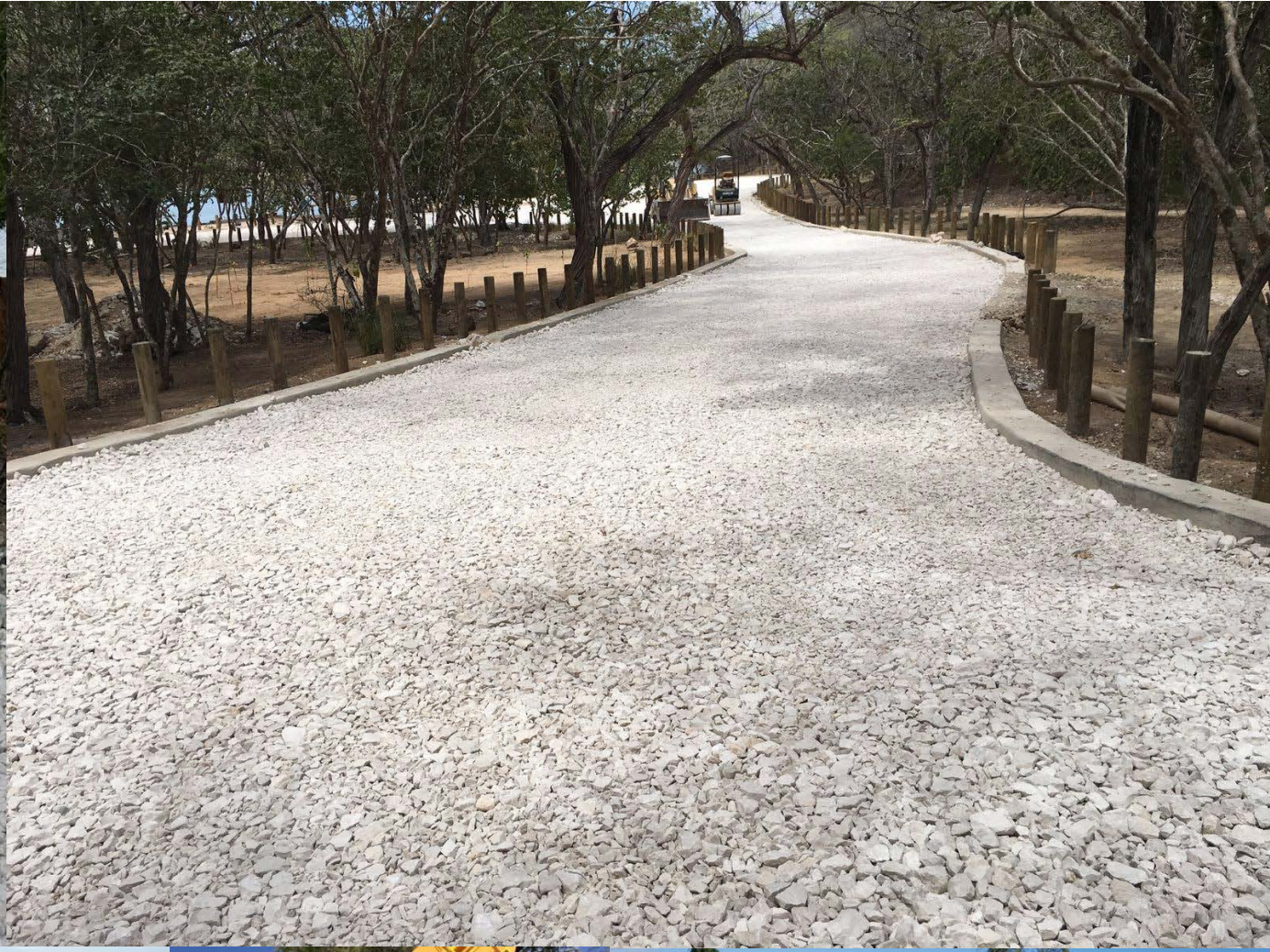
POSSIBLE APPLICATION AND NEEDS FOR PUERTO RICO AND BEYOND

1. Helping to demonstrate the benefits of restoration efforts (land/boat based water quality measurements are limited by time and funding) – Guánica WWTP
2. Helping to reinforce the identification of significant pollution sources
3. Further resolving nearshore and shallow site measurements
4. Ability to report parameter measurements with estimated error
5. Efforts in Lakes
6. Support for higher resolution DEMs or Lidar type products
7. Encouraged by user-friendly products in development
8. Cognizant of challenges with sediment and limited magnitude of change















Sustained Watershed Management

- Building Sustainable sources of Funding
- Co-management Guánica Dry Forest
- Ecotourism
- Puerto Rico Tourism Company

Next Steps:

- Coordination Efforts Summarized Report
- List of all funding sources and partners
- WMP Update
- Private Funders
- Conversations with Puerto Rico Government and NOAA for long term coordination efforts funding



INSTITUTIONAL CAPACITY BUILDING

Native Plants Nursery

- NFWF Funds
- More than 60,000 plants produced
- Restoration Projects across the Island
- Expected to produce over 100,000 planta by the end of the year
- Additional 2 acres of land From Yauco Municipality to expand maturing area










Monitoring Equipment

- HACH 2100Q Portable Turbidimeter
- HACH SL1000 Portable Nutrient Multiparameter
- YSI Multiparameter
- HANA Ammonia Medium Range Portable Photometer - HI96715
- IDEXX Quanti-Tray System for bacteria






Restoration Equipment

- 5 4x4 Pick up trucks
- 1 6m Dump Truck
- 1 Backhoe
- 1 Bulldozer
- 1 Compacting Roller
- 1 Skid Steer
- 3 water truck
- 6 trailers
- Hydromulcher

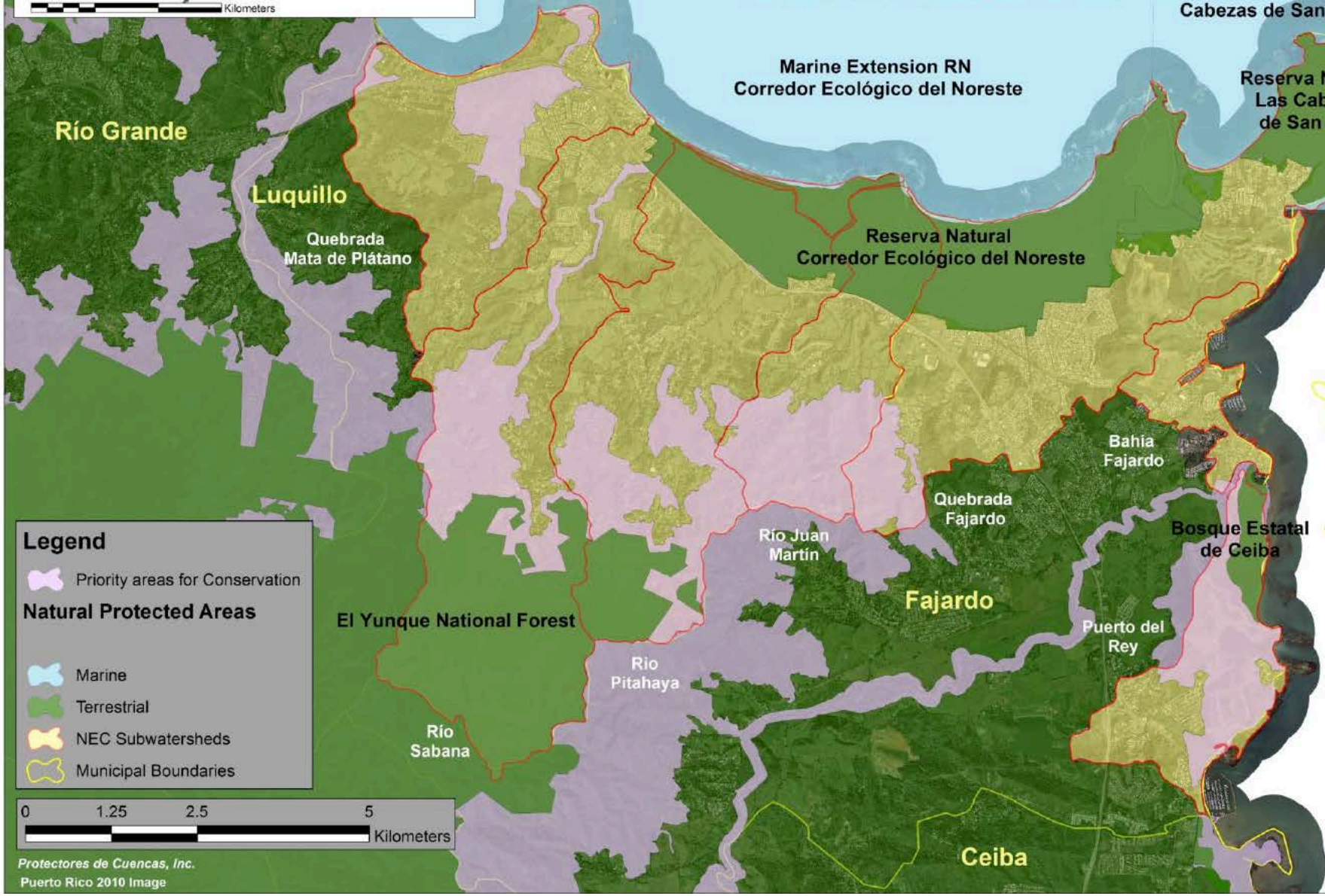




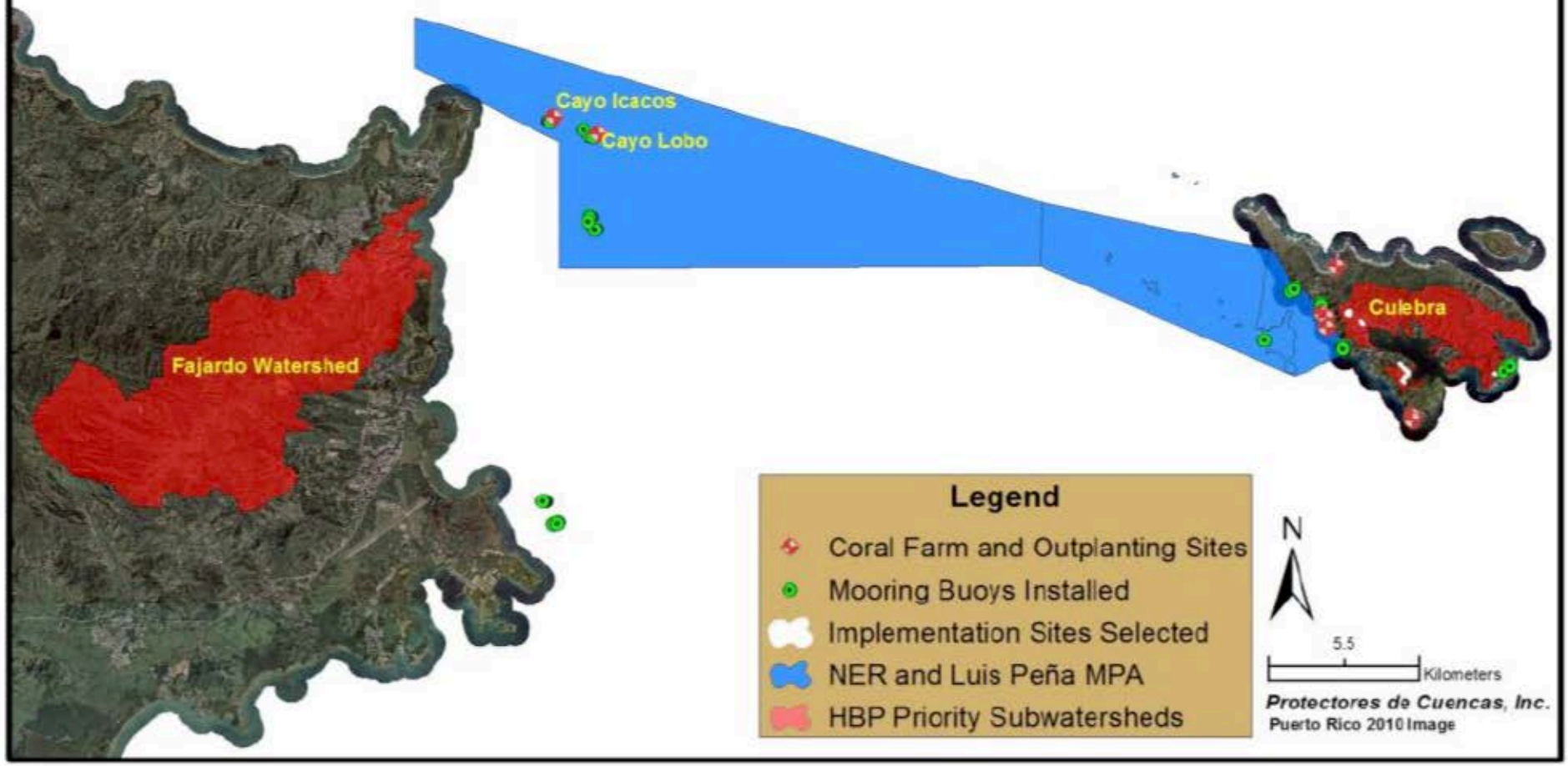


Staff:

- 5 Technical Personnel
- 20 General Labor experts in BMP and Green Infrastructure Implementation


Kilometers
Cabezas de San
Marine Extension RN
Corredor Ecológico del Noreste
Reserva
Las Cab
de San
Río Grande
Luquillo
Quebrada
Mata de Plátano
Reserva Natural
Corredor Ecológico del Noreste
Bahía
Fajardo
Quebrada
Fajardo
Río Juan
Martín
Bosque Estatal
de Ceiba
Fajardo
El Yunque National Forest
Puerto del
Rey
Rio
Pitahaya
Río
Sabana
Ceiba
Legend
Priority areas for Conservation
Natural Protected Areas
Marine
Terrestrial
NEC Subwatersheds
Municipal Boundaries
0
1.25
2.5
5
Kilometers
Protectores de Cuencas, Inc.
Puerto Rico 2010 Image

NER Cordillera and Culebra LBSP Reduction and Coral Population Enhancement Selected Sites











Partners



Yauco

Guánica

Guayanilla

Lajas

The University of Texas at Austin
Teresa Lozano Long Institute of Latin American Studies



THANK YOU!

Paul Sturm

www.ridgetoreefs.org

paul@ridgetoreefs.org



Roberto Viqueira

www.protectoresdecuencas.org

rviqueira@protectoresdecuencasinc.org

The City College of New York

NOAA CREST

JPSS

Joint Polar Satellite System

VIIRS retrievals of *Karenia brevis* harmful algal blooms in the West Florida Shelf using Neural Networks.

Sam Ahmed[1], Ahmed El-Habashi[1] and Vincent Lovko[2].

NOAA Collaborators Drs. Richard P. Stumpf[3] and Michelle C. Tomlinson[3]

[1]NOAA CREST Optical Remote Sensing Laboratory, the City College of the City University of NY, USA

[2]Mote Marine Laboratories, Sarasota FL 34236

[3]NOAA National Centers for Coastal Ocean Science, 1305 East-West Highway code N/SCI1 Silver Spring, MD 20910, USA

Outline

- Background of Harmful Algal blooms (HABs) in West Florida Shelf (WFS)
- Neural Networks (*NN*) algorithm architecture
- *Karenia Brevis* Harmful Algal bloom (*KB*-HABs**)** retrieval approach
- Comparison of in-situ measurements vs. retrieval algorithms
- Consecutive satellite images showing variations
- Field measurements
- Conclusion

Background of *KB* HABS in WFS



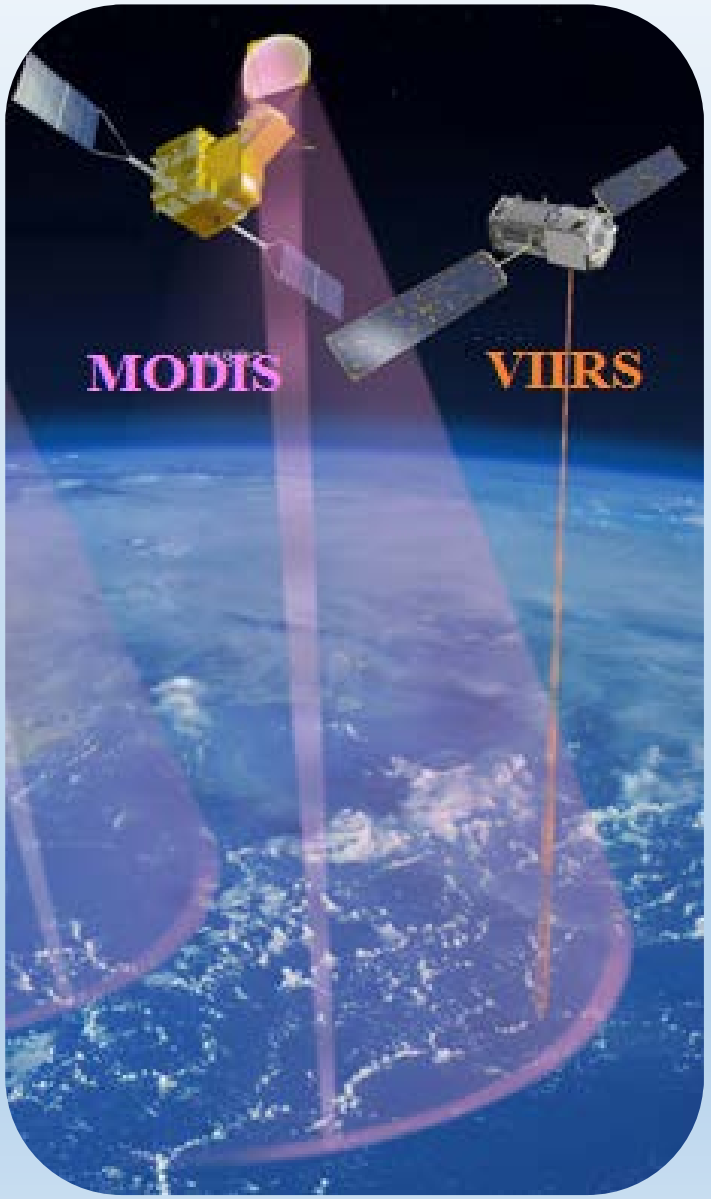
- Harmful algal blooms, occur when colonies of phytoplankton grow out of control while producing toxic or harmful effects on people, fish, shellfish, marine mammals and birds.

- In united states it has been estimated that $30-$70 million is lost annually as a result of HABs (Fisher et al.). Recent July 4th 2016 bloom had a major effect on economy and health.

MODIS & VIIRS satellite capability for *KB* HABs detections

- MODIS retrieval of *KB* uses fluorescence line height technique (nFLH) which requires 678nm chlorophyll fluorescence band

- 678 nm band not available on VIIRS providing impetus for development of NN technique, which uses as inputs 486, 551 and 671 nm available in VIIRS.



Neural Networks (NN) Algorithm Architecture.

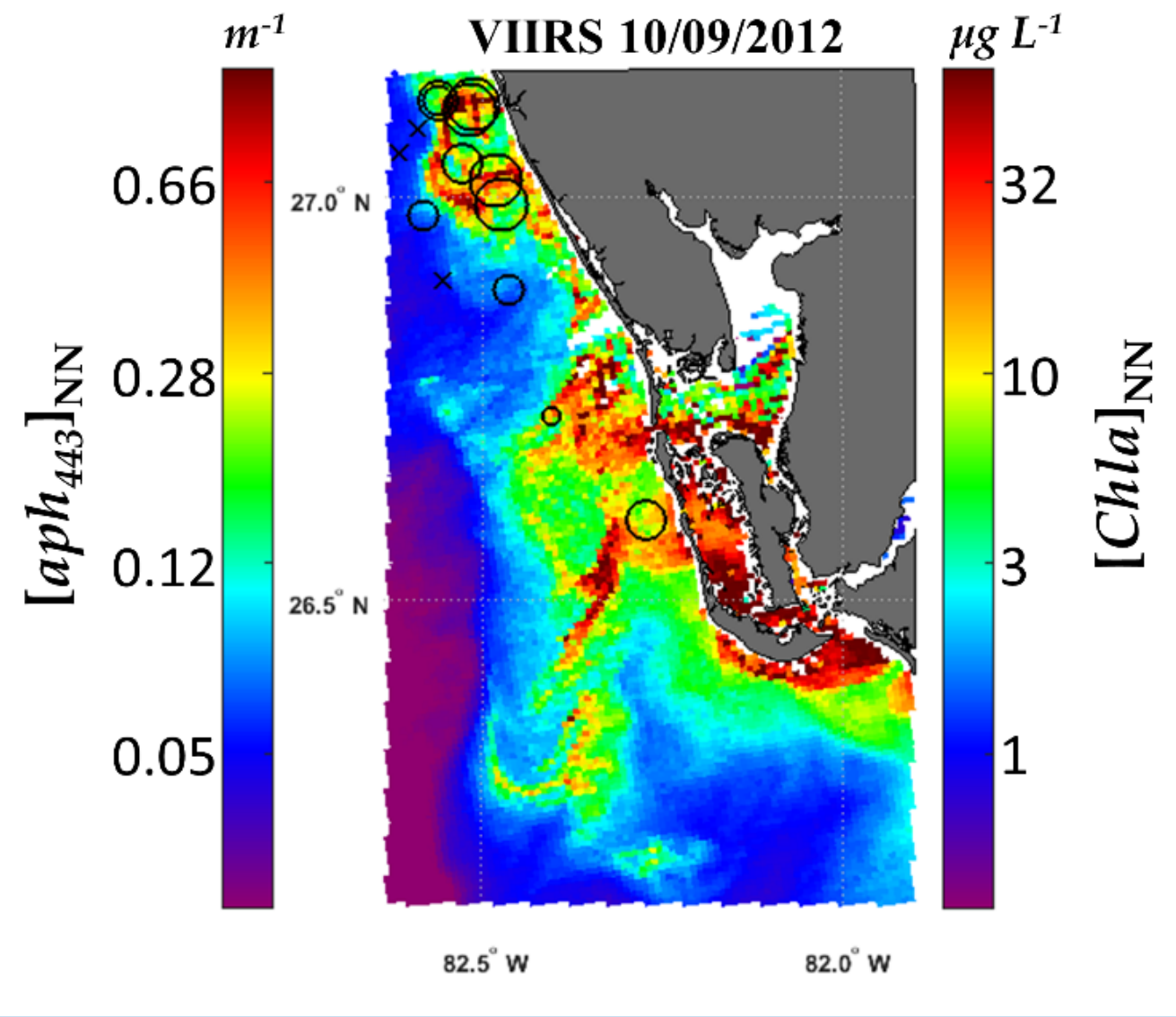
- A multilayer perceptron neural network (NN) was developed based on a 4 component bio-optical (pure water, phytoplankton, CDOM and NAP): 20,000 simulated dataset generated as a random variables, based on a wide range of coastal and oceanic NOMAD IOPs, used in a forward bio-optical model based on radiative transfer, to generate 20,000 sets of Rrs at 486,551 and 671 nm (VIIRS bands)/

- NN was trained on 10,000 and tested and validated on remaining 10,000 simulated dataset and field measurements.

- Note: NN uses Rrs from VIIRS as inputs at 486, 551 & 671 nm, all relatively long wavelengths which are not greatly impacted by atmospheric correction inadequacies.

- Output of IOPs (aph etc) all at 443 which at the peak of aph and thus exhibit most variation (We are only interested at aph443)

Example of VIIRS *NN* retrievals of a_{ph443}, and its conversion to equivalent [*Chla*].



- Reflectance data obtained from the NASA Level 2, L2gen data processing system.
- Any individual pixel is excluded from the image if it has been flagged land, cloud, failure in atmospheric correction, bad navigation quality, both high and moderate glint, negative Rayleigh-corrected radiance

a_{ph443} : phytoplankton absorption at 443 nm.

[*Chla*] : Chlorophyll-a concentrations

Approach applied in WFS for *KB*-HABs Retrievals

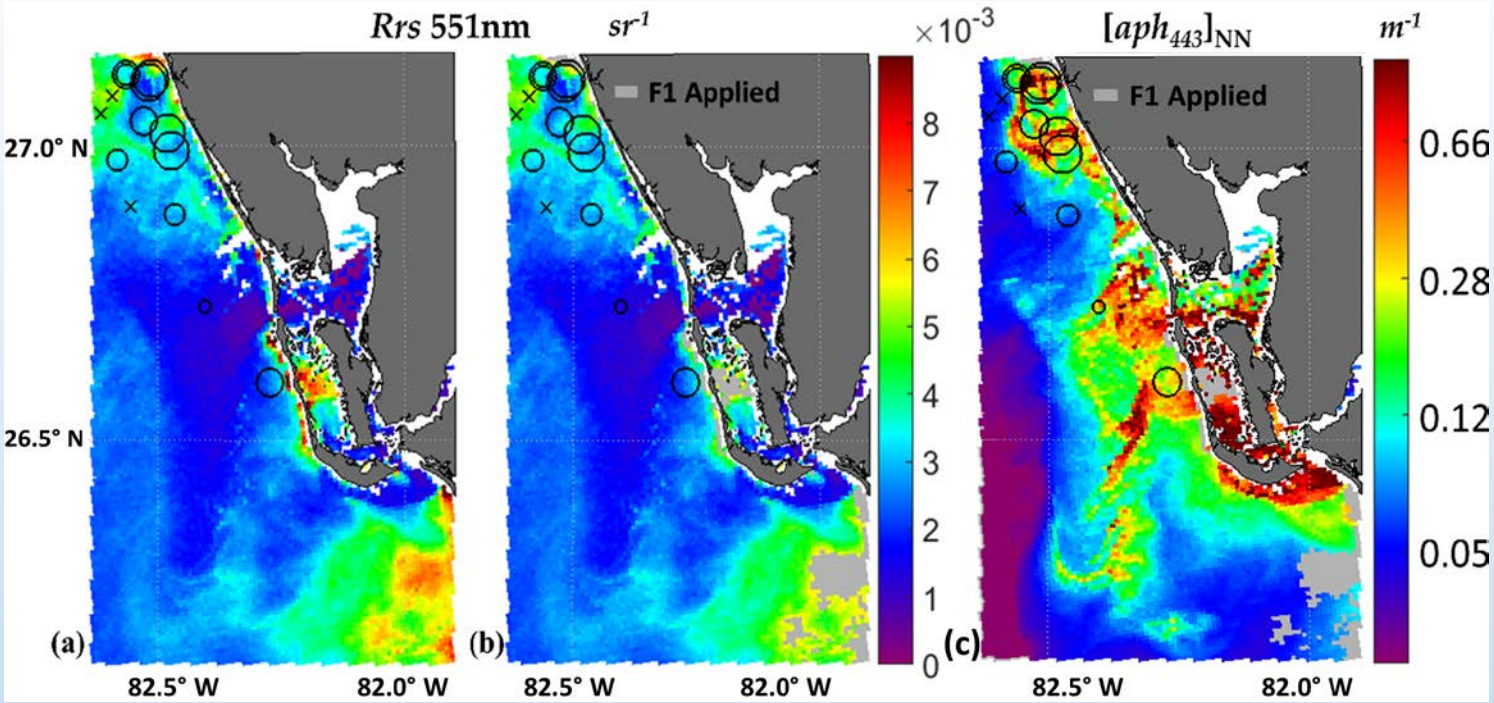
- **First** we relate VIIRS Rrs (486,551,671) to $a_{ph}443$ using NN for estimation of $a_{ph}443$ which is approximately proportional to [*Chla*].

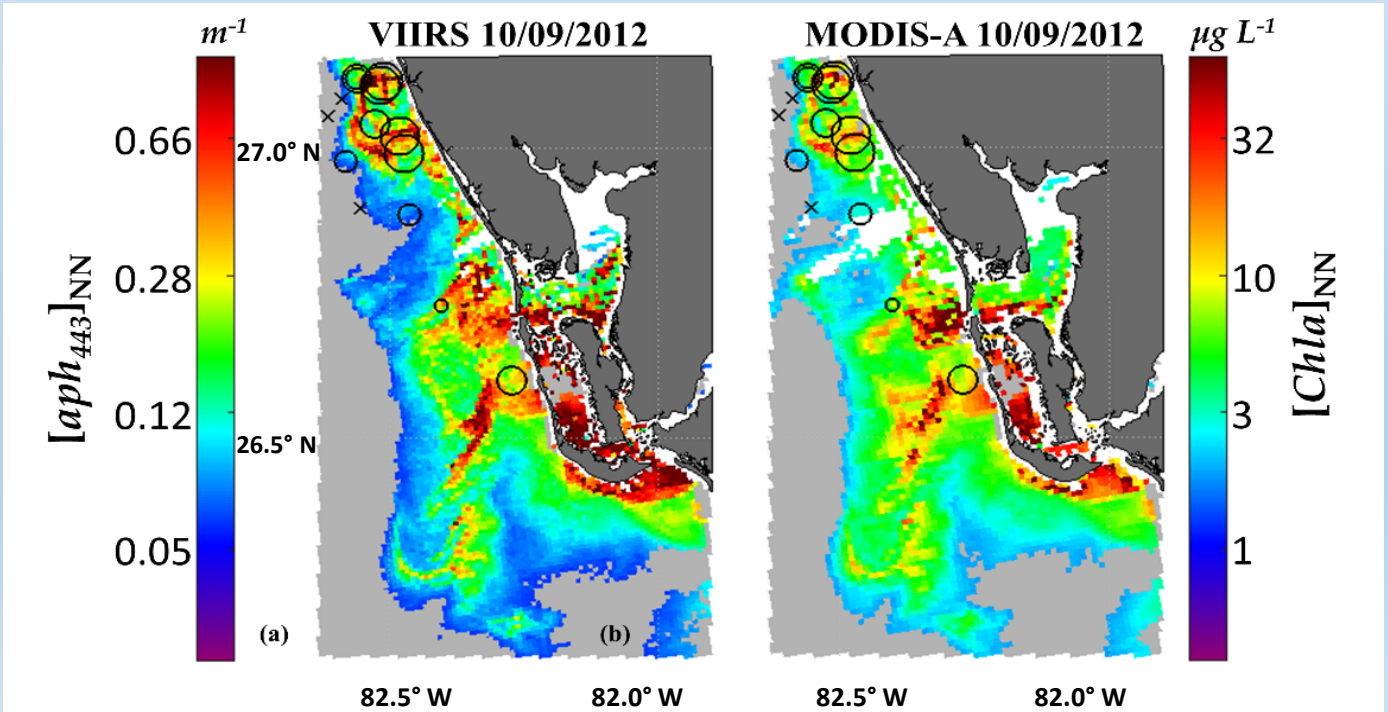
- **Then**, in a second critical step, we evolve limiting criteria which make use of two facts (*Cannizzaro, 2009*)

I. *low backscatter* $\boldsymbol{bb_p551}$	$\leq$	***max specific value.***	← *KB* blooms are ineffective backscatterer
&Equiv. $\boldsymbol{Rrs_{551}}$	$\leq$	$\boldsymbol{0.006\ sr^{-1}}$ ***Filter F1***	
II. $\boldsymbol{a_{ph443}}$	$\geq$	***min specific value.***	
$\boldsymbol{a_{ph443}}$	$\geq$	$\boldsymbol{0.061\ m^{-1}}$ ***Filter F2***	

These limiting criteria are applied to retrieved VIIRS retrievals of a_{ph443} & Rrs_{551} to effectively delineate and quantify *KB*.

Blooms on 10/09/2012





KB in-situ measurements:

Cell Counts/L Classification:
- x *Not Observed*
- o *Very Low (1-10,000)*
- ○ *Low (10,000-100,000)*
- ◯ *Medium (100,000-1,000,000)*
- ◯ *High (1,000,000+)*

Successive applications of backscatter filter F1, and min a_{ph443} filter F2 (light grey) to NN VIIRS and MODIS retrievals so residual images show *KB* HABs

NN VIIRS retrievals compared against near-coincident in-situ *Karenia Brevis* (*KB*) cell counts (2012-2016)

- To obtain sufficient numbers of points for statistically meaningful comparisons all *Karenia Brevis* cell counts collected by Florida Fish and Wildlife Conservation Commission (FWC) over 2012-16 period were compared to all valid near coincident VIIRs retrievals. Comparisons of retrievals V in-situ shown in the coming slides for following algorithms:

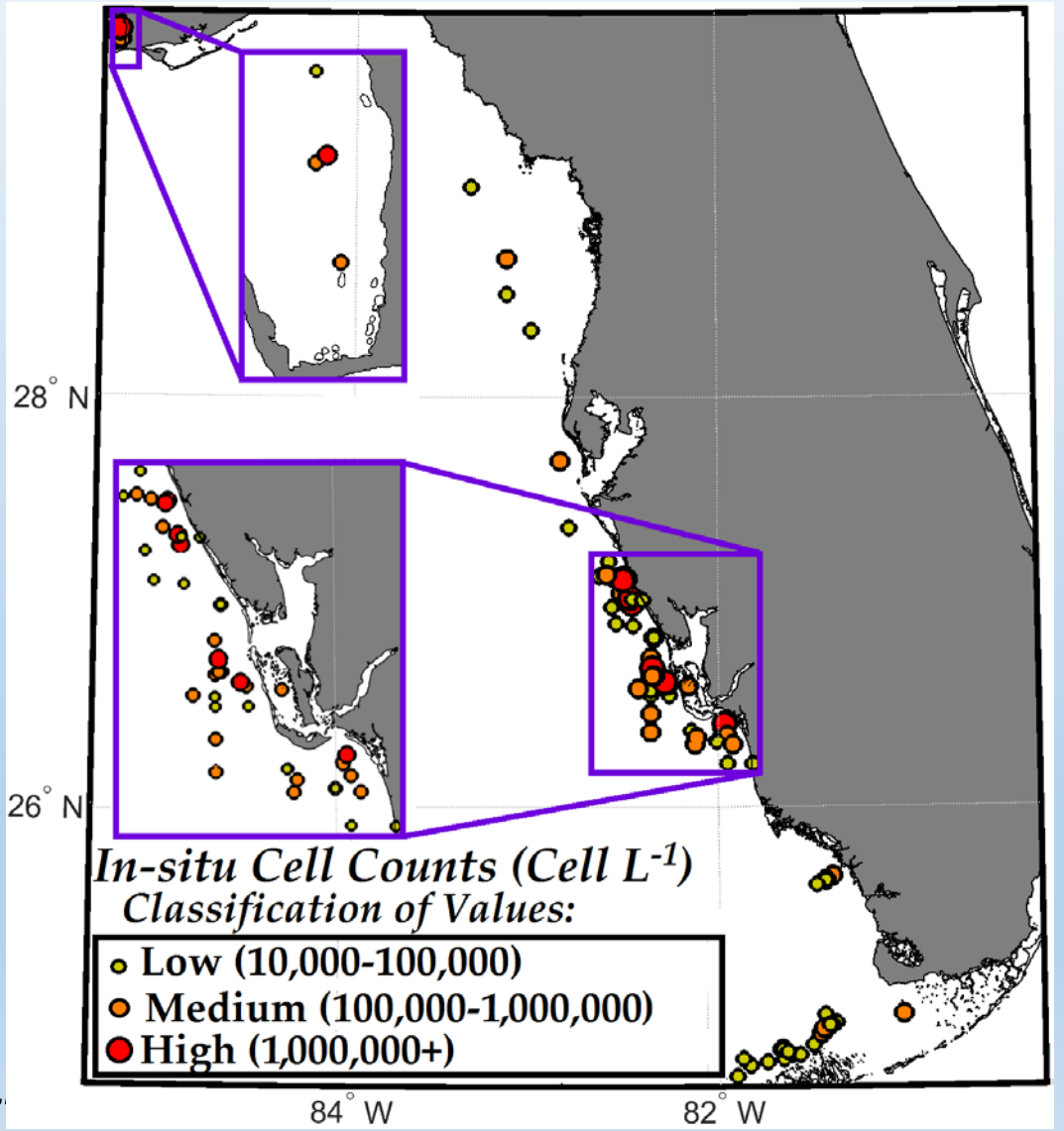
  ***NN* (Neural Network)**

  (Ocx) **Ocean Color product for chlorophyll-a (NASA).**

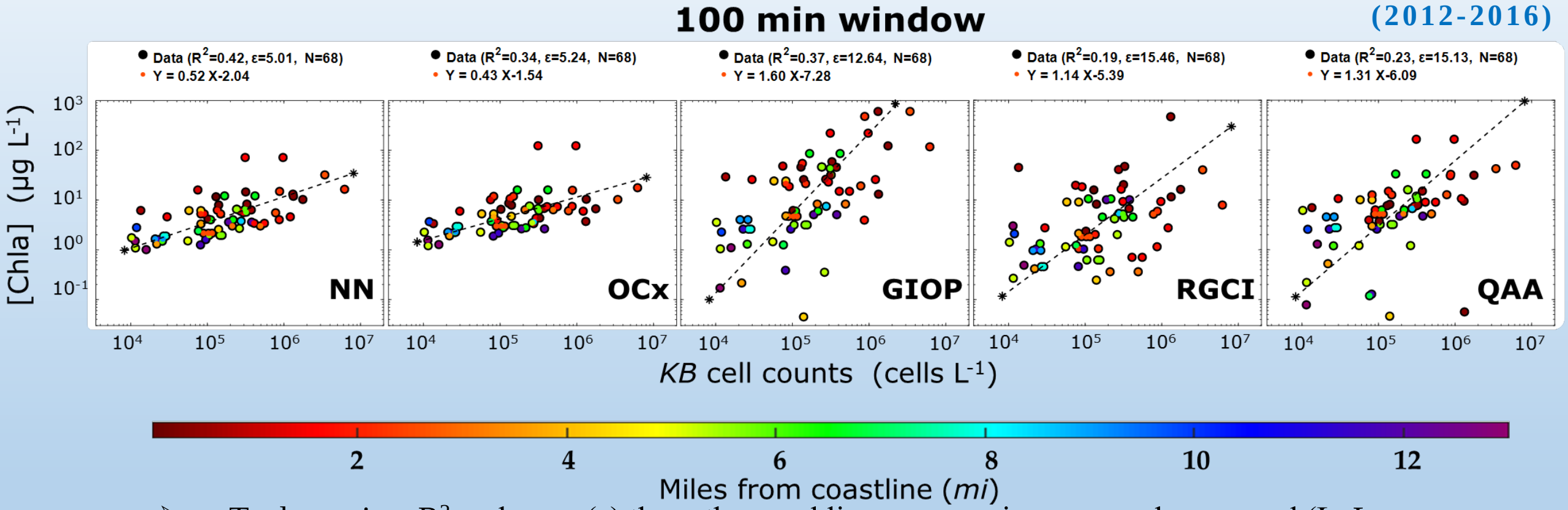
  (GIOP) **Generalized Inherent Optical Property model**

  (QAA_5) **Quasi-Analytical Algorithm version 5**

  (RGCI) **Red Green chlorophyll-*a* Index [*Chla*] retrievals for WFS [*L*** ***Qi, C. Hu 2015*]:**



Retrieval comparisons using NN and other retrieval algorithms against in-situ cell counts

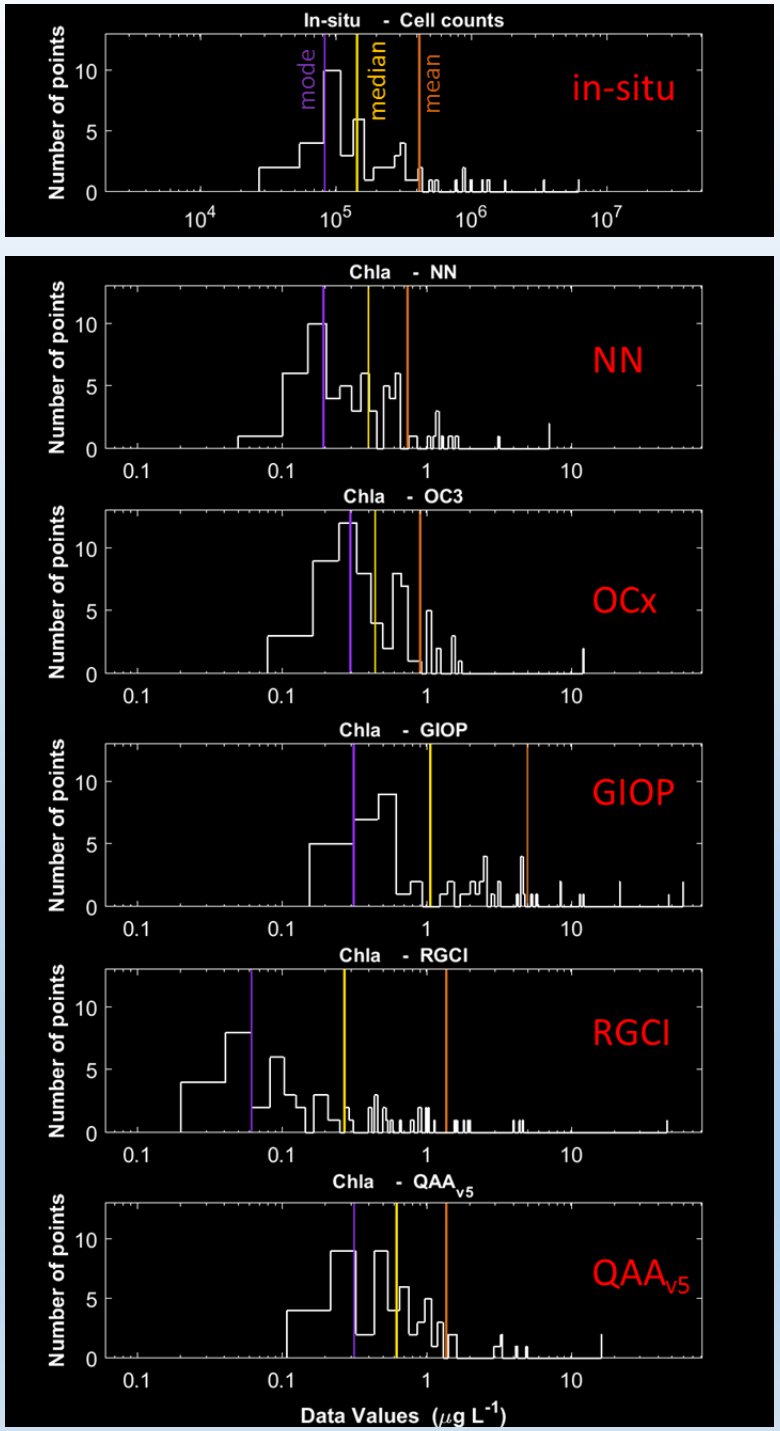


- To determine R^2 and error (ε) the orthogonal linear regression approach was used (L. Leng et al 2007).

Showing in-situ comparison for the 93 available match-ups points for 100 minutes overlap windows with in-situ observations obtained using the different algorithms (**NN, OCx, GIOP, RGCI**, and **QAA_{v5}**).

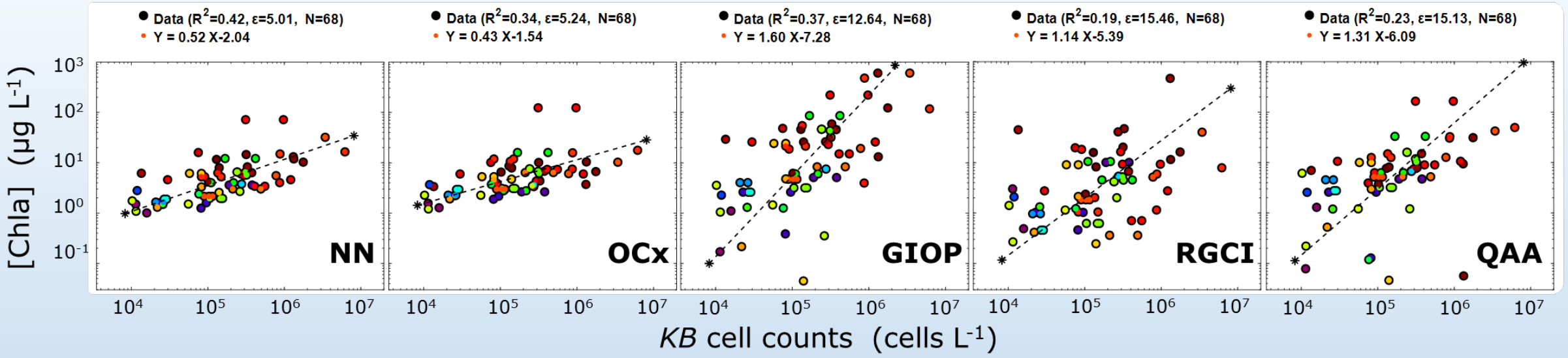
Data distribution comparison for *KB cell counts* in-situ measurements and equivalent their [Chla] retrieval algorithms

KB in-situ & retrievals algorithms		[*Chla*] data values ($\mu g \cdot L^{-1}$)						
		mean	**median**	**mode**	**STD**	**min**	**max**	**N**
In-situ	**VIIRS 100 minutes window**	4.1	1.4	0.8	9	0.1	62	68
NN		7.4	3.9	1.9	12	0.99	71	68
OCx		9	4.4	2.9	20	1.19	122	68
GIOP		50	10.6	3.1	118	0.04	597	68
RGCI		13.7	2.7	0.6	56	0.24	461	68
QAA_{v5}		13.7	6.2	3.2	28	0.05	163	68

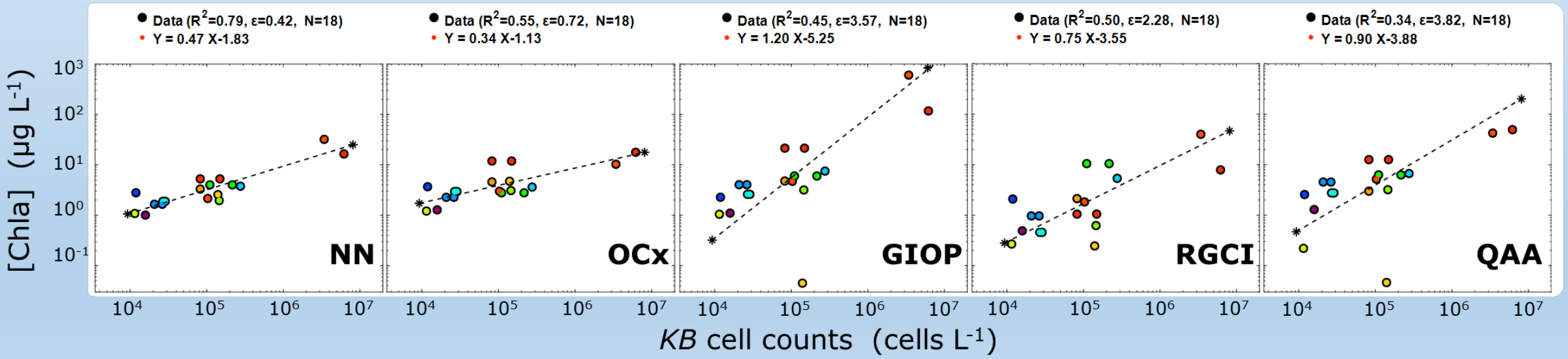


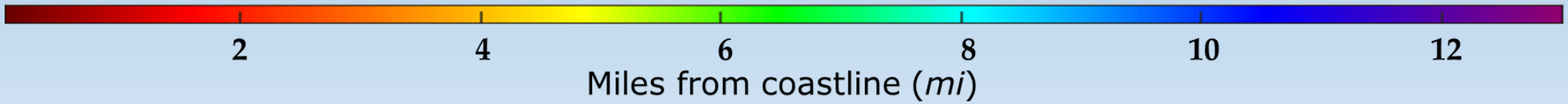
To determine R^2 and error (ε) the orthogonal linear regression approach was used (L. Leng et al 2007), where errors are assumed to exist for both variables. The error (ε) is calculated as the sum of orthogonal distances. Results are shown in the next slide

100 min window



15 min window





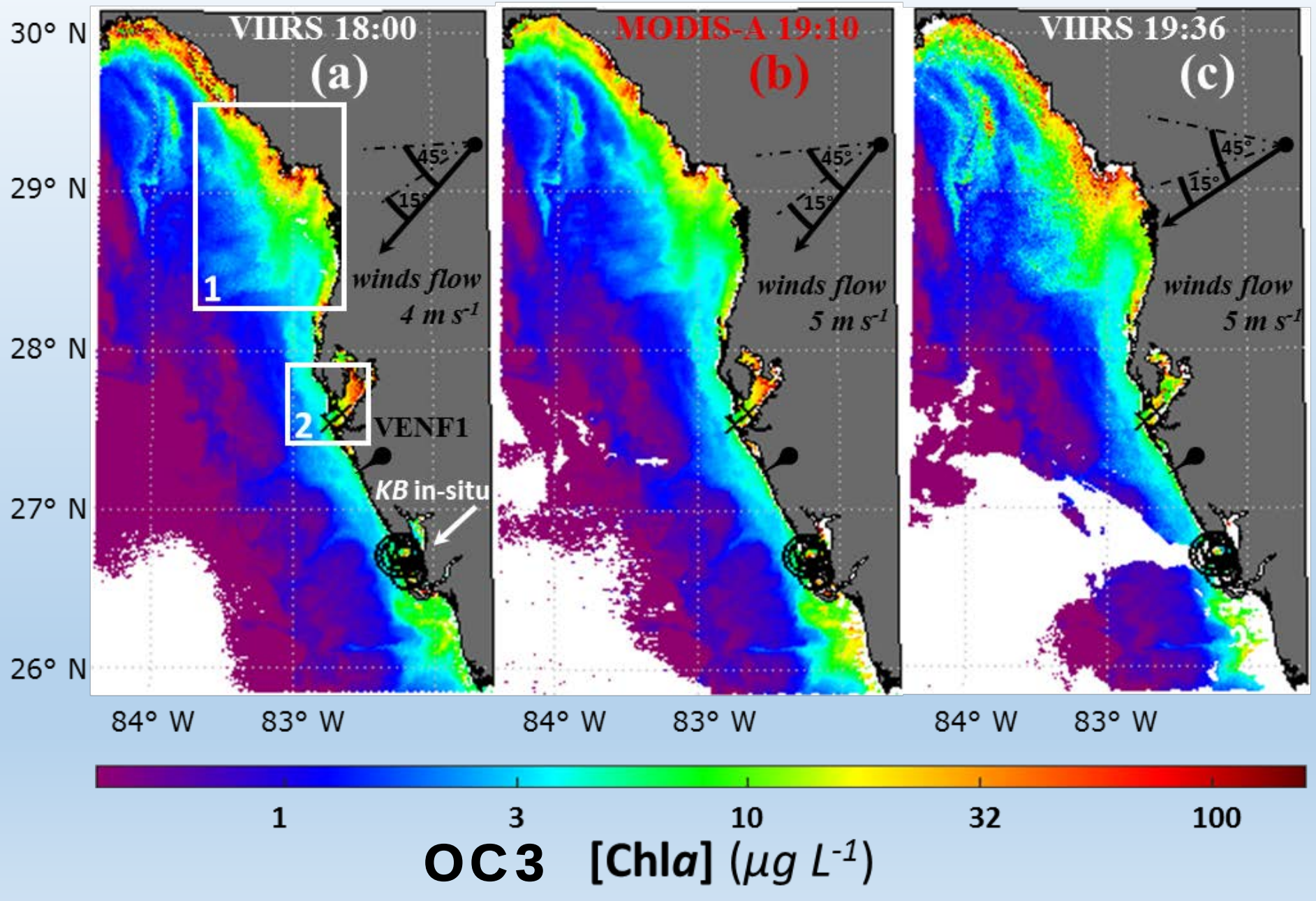
Summary table

y-axis [*Chla*] ($\mu g \cdot L^{-1}$)	*x-axis* ***KB*** Cell Counts ($cells\ L^{-1}$)	R^2	ε	Slope & Intercept	N
NN	**VIIRS 100 minutes window**	0.42	5.01	$y = 0.52\,x - 2.04$	68
OCx		0.34	5.24	$y = 0.43\,x - 1.54$	68
GIOP		0.37	12.64	$y = 1.60\,x - 7.28$	68
RGCI		0.19	15.46	$y = 1.14\,x - 5.39$	68
QAA		0.23	15.13	$y = 1.31\,x - 6.09$	68
NN	**VIIRS 15 minutes window**	0.79	0.42	$y = 0.47\,x - 1.83$	18
OCx		0.55	0.72	$y = 0.34\,x - 1.13$	18
GIOP		0.45	3.57	$y = 1.20\,x - 5.25$	18
RGCI		0.50	2.28	$y = 0.75\,x - 3.55$	18
QAA		0.34	3.82	$y = 0.90\,x - 3.88$	18

Table: Statistics of comparison for retrieval algorithms and there successful retrievals against in-situ observations (2012-2016)

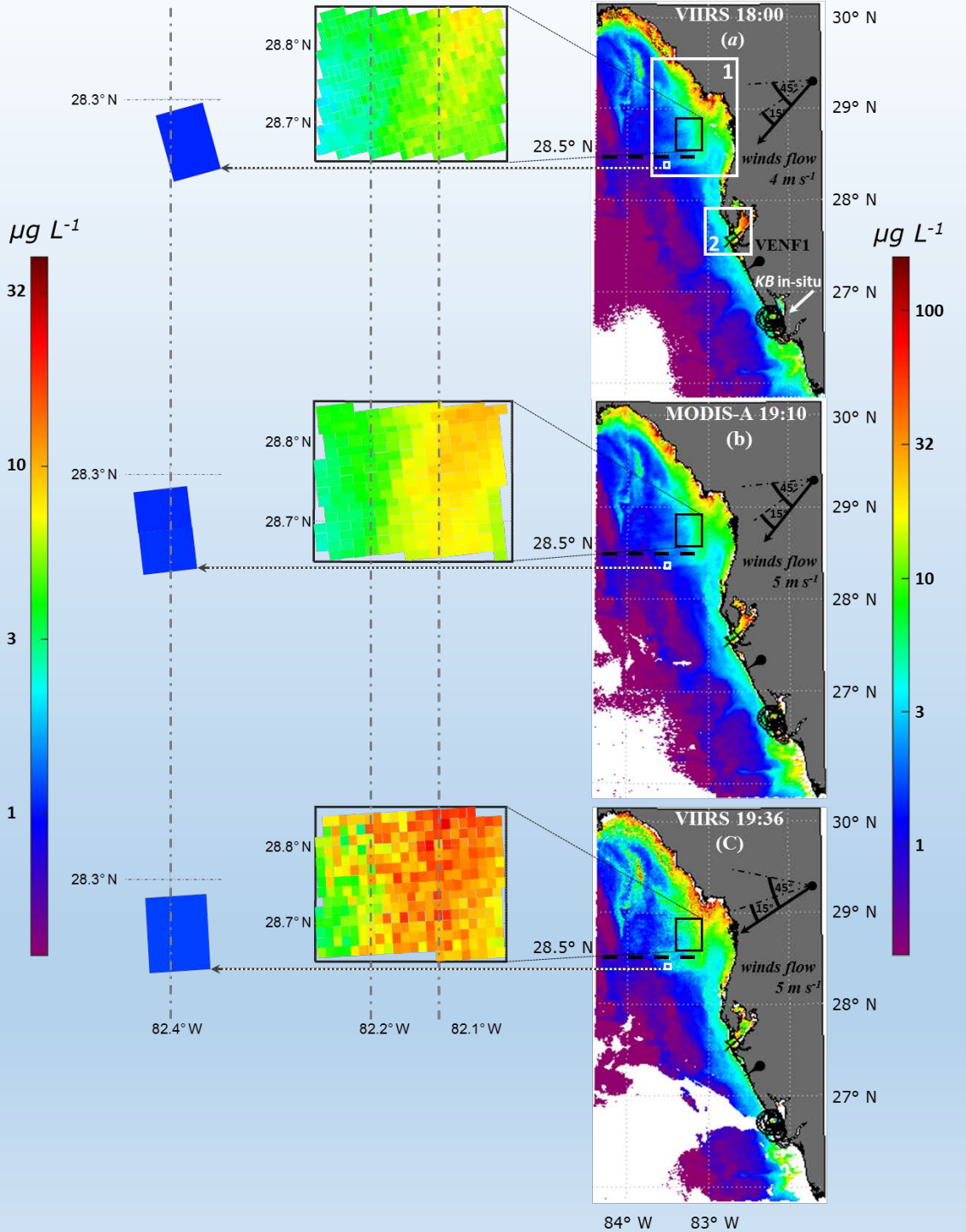
Consecutive satellite images on Nov. 3rd 2014

Showing variation in bloom.

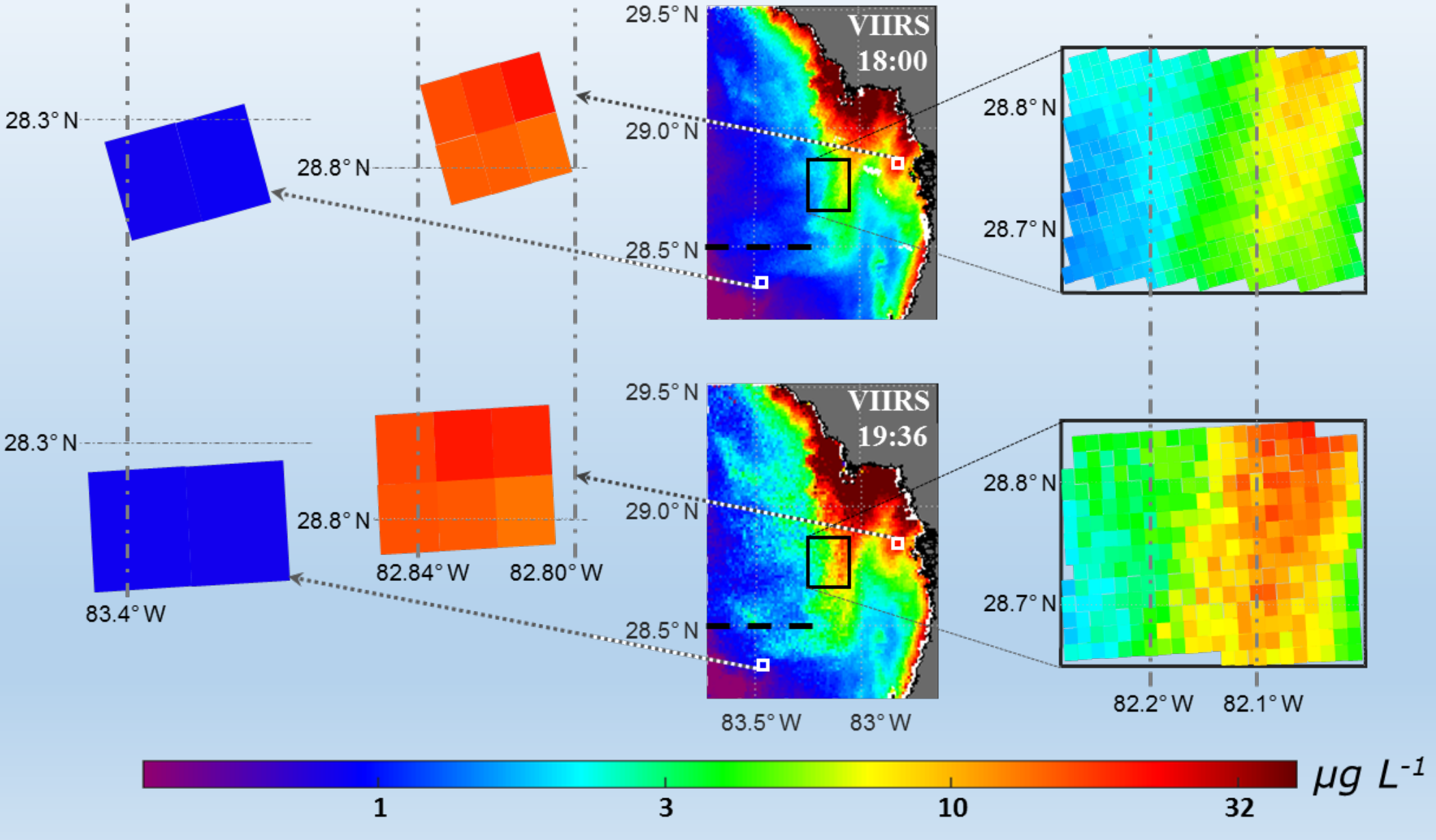


Changes in bloom for consecutive satellite images of region 1 using retrieved OC3 [*Chla*].

- The bloom, as delineated by the [*Chla*] color contour in the images, appears, qualitatively, to increase in concentration and expand in the southwest direction over the 96 minute interval between the consecutive overlapping VIIRS-MODIS-VIIRS images.

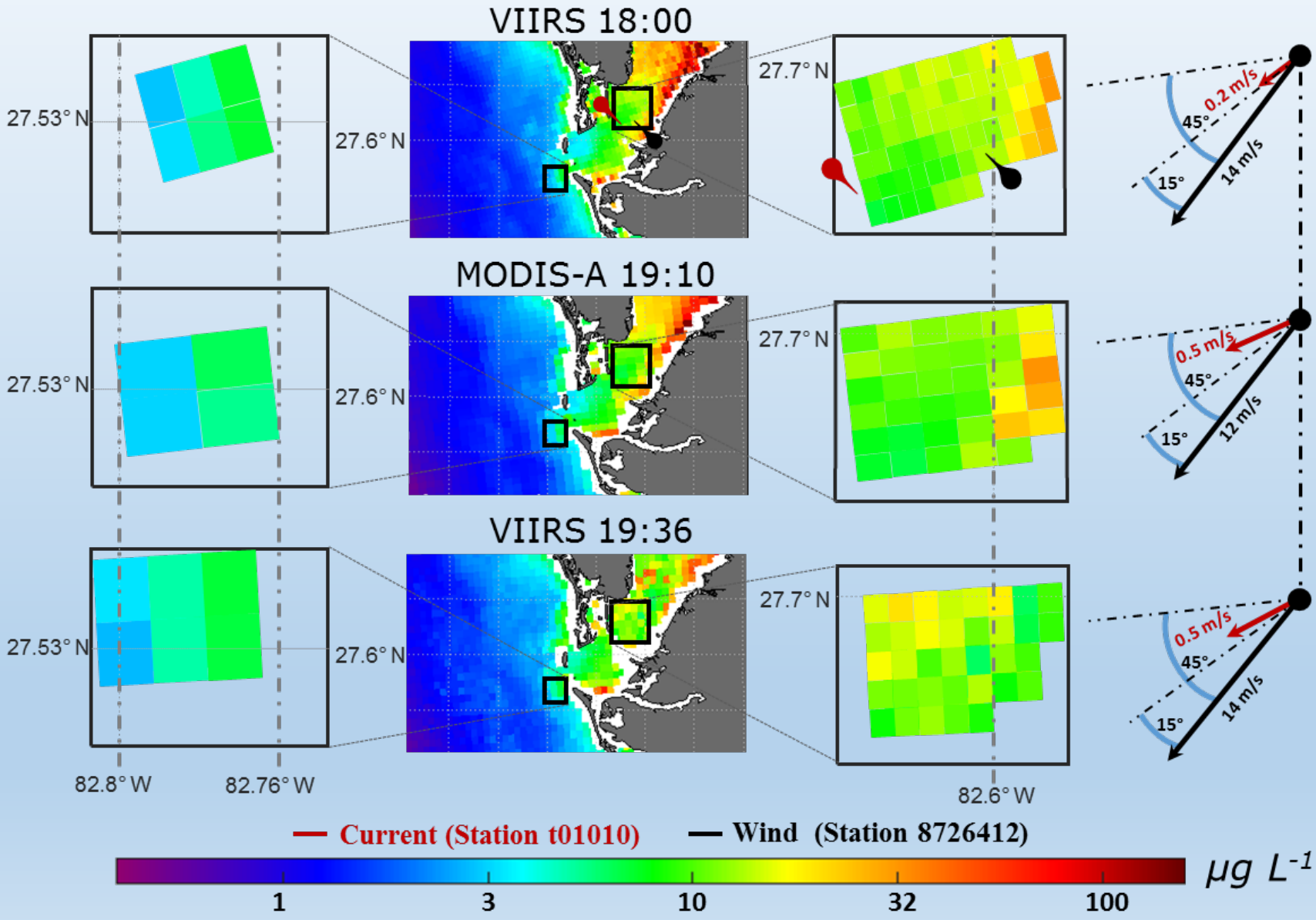


region 1 using NN retrieved [*Chla*].

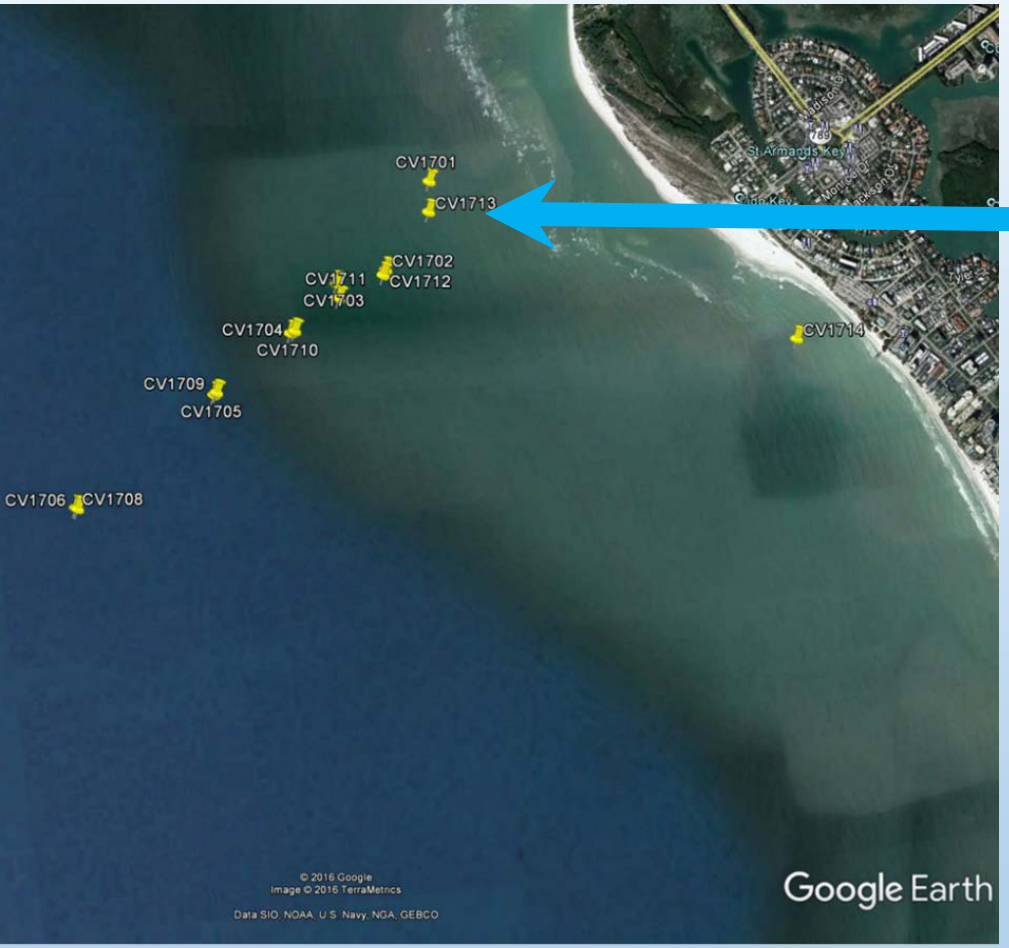


NN retrievals from Tampa Bay, Region 2.

Figure shows VIIRS and MODIS-A sequential retrievals from Tampa Bay, where a bloom seems to shrink in [*Chla*] densities opposite to the wind and current direction, implying that there are a complexity of factors at work, possibly including downwelling.



Results of field measurements showing temporal variability on 1/19/2017



Station	Depth (m^{-1})	Lat. (°)	Long. (°)	Start Time (*GMT*)	End Time (*GMT*)	*K. brevis* ($cells\ L^{-1}$)	Time diff (*minutes*)
CV1701	0.7	27.31836	-82.59587	17:20	17:25	**7,280,000**	**120**
CV1713	0.7	27.31713	-82.59606	19:21	19:25	**1,552,000**	
CV1702	0.7	27.31500	-82.59831	17:48	17:52	**1,776,000**	**87**
CV1712	0.7	27.31480	-82.59846	19:15	19:19	**1,326,000**	
CV1703	0.7	27.31467	-82.60061	18:00	18:04	**1,024,000**	**68**
CV1711	0.7	27.31408	-82.60059	19:09	19:12	**1,110,000**	
CV1704	0.7	27.31296	-82.60277	18:07	18:12	**964,000**	**54**
CV1710	0.7	27.31289	-82.60298	19:03	19:06	**590,000**	
CV1705	0.7	27.31077	-82.60677	18:18	18:22	**642,000**	**37**
CV1709	0.7	27.31085	-82.60664	18:55	18:59	**576,000**	
CV1706	0.7	27.30681	-82.61356	18:27	18:32	**952,000**	**21**
CV1708	0.7	27.30686	-82.61364	18:48	18:51	**690,000**	

Figure Transect of outward and return legs of field measurements.

These results illustrate both the intra pixel variations that can typically occur (as well as inter pixel variations) and also confirm the temporal variations that can be expected. The relative contributions of drift or upwelling/downwelling to the results are not known.

Conclusion

- The use of NN retrievals of $a_{ph}443$ from VIIRS show promise as a viable algorithm for the Florida coastal regions with complex water conditions.
- Comparisons against in-situ measurements show that VIIRS [Chl$a$] data retrievals are significantly improved for all algorithms for shorter overlap time windows.
- Show important impact of temporal variations on retrieval accuracies.
- Further detailed comparisons with in-shore in-situ measurements are planned and considerations of subpixel variability addressed.

Acknowledgment

We thank NOAA JPSS and NOAA-Crest for the support to continue this work.

Thank you