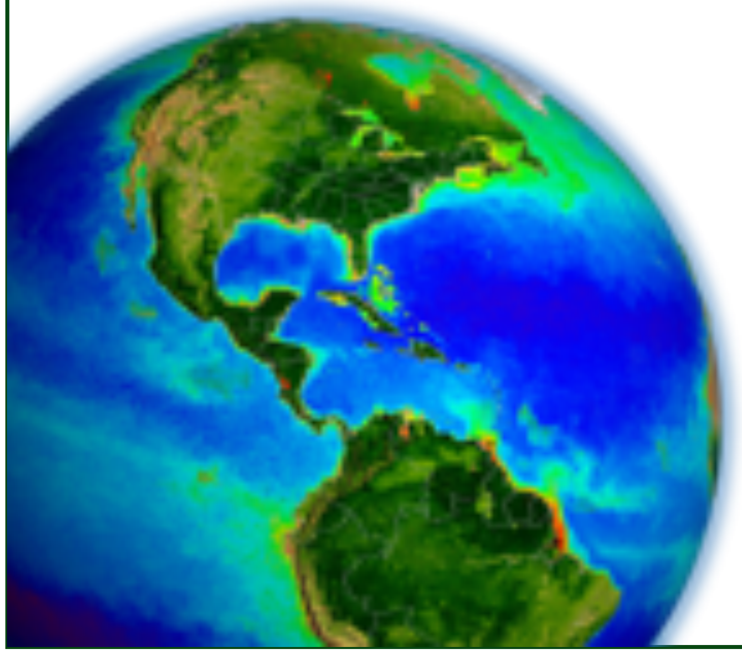
MODIS/VIIRS Science Team Ocean Discipline Report

Bryan Franz

and the

Ocean Discipline Science Team



MODIS/VIIRS Science Team Meeting

19 Nov 2020

Virtual

Contents

MODIS/VIIRS Ocean SIPS Standard Production

Product	POC	Sensor
$R_{rs}(\lambda)$, AOT, Angstrom	*Franz*	*MODIS, VIIRS*
Chlorophyll a	*Franz (Werdell, Hu)*	*MODIS, VIIRS*
$K_d(490)$	*Franz (Werdell)*	*MODIS, VIIRS*
POC	*Stramski*	*MODIS, VIIRS*
PIC	*Balch*	*MODIS, VIIRS*
PAR	*Frouin*	*MODIS, VIIRS*
nFLH	*Westberry*	*MODIS*
IOPs	*Werdell*	*MODIS, VIIRS*
SST (11um)	*Minnett (Kilpatrick)*	*MODIS, VIIRS**
SST (4um)	*Minnett (Kilpatrick)*	*MODIS*

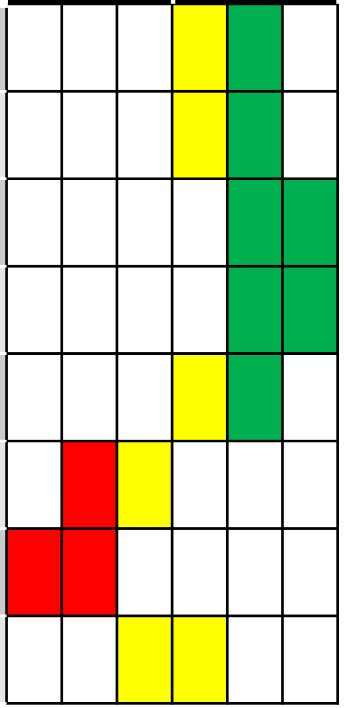
* orphaned product (no PI selected in current science team)

The Ocean SIPS continues to produce and the OB.DAAC continues to distribute all products.

No impact on forward stream production due to COVID-19, despite limited on-site activity.

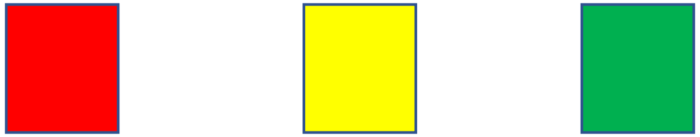
MODIS SR Algorithm Maintenance Proposals

PI	Proposal Title	COVID Impact
W. Balch	Particulate Inorganic Carbon	
B. Franz	Remote Sensing Reflectance, Chlorophyll, Diffuse Attenuation	
R. Frouin	Photosynthetically Available Radiation	
P. Minnett	Sea Surface Temperature	
T. Westberry	Fluorescence Line Height	
A. Mannino	HPLC pigments	
N. Nelson	BBOP	
D. Siegel	Plumes & Blooms	



field/laboratory work

Productivity Impact due to COVID-19



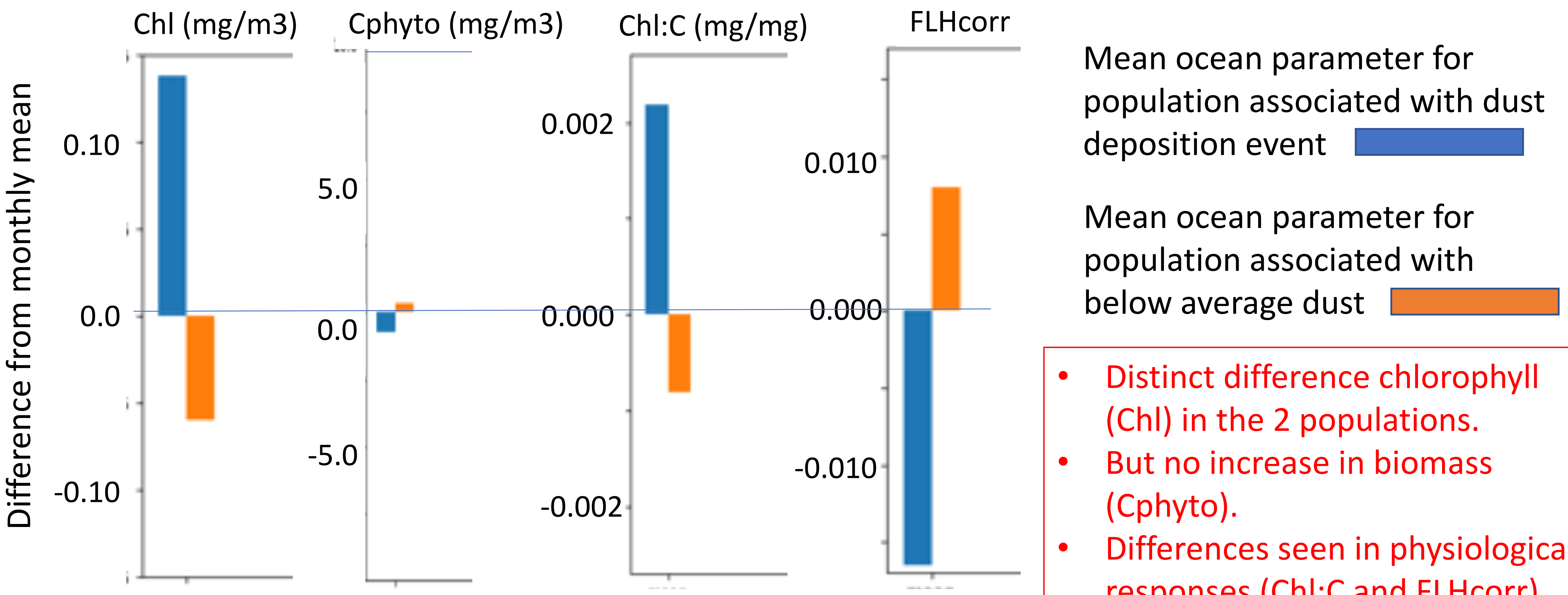
0% 50% 100%

TASNPP Ocean Proposals & COVID Impacts

PI	Proposal Title	COVID Impact
M. Behrenfeld	Merging Active and Passive Ocean Observations to Advance Understanding of Climate Impacts on Global Carbon Stocks and Phytoplankton Physiology	
B. Franz	Advancing the Quality and Continuity of Marine Remote Sensing Reflectance and Derived Ocean Color Products from MODIS to VIIRS	
R. Frouin	Estimating the Fraction of Photosynthetically Available Radiation Absorbed by Live Phytoplankton from MODIS and VIIRS Data	
C. Rousseaux	Combining Data Assimilation with an Algorithm to Improve the Consistency of SeaWiFS, MODIS and VIIRS Chlorophyll: Continuing a Multidecadal, Multisensor Global Record	
K. Knobelspiesse	Joint MISR/MODIS Ocean Color Atmospheric Correction with a New Algorithm that Utilizes Reflected Sun Glint	
P. Koner	Physical Deterministic Sea Surface Temperature from MODIS and VIIRS Radiances	
T. Kostadinov	Carbon Based Phytoplankton Size Classes Using Multi Platform Ocean Color Observations and Earth System Models: inter Annual Variability and Trend Power Analysis	
A. Mannino	Support of NASA MODIS and VIIRS Ocean Science Teams and Research with Quality Assured HPLC Pigment Analysis	
P. Minnett	Merging Optimal Estimation and Multi Channel Atmospheric Corrections for Accurate Sea Surface Temperatures from MODIS and VIIRS	
L. Remer	Understanding Airborne Fertilization of Oceanic Ecosystems from Analysis of MODIS, VIIRS and CALIOP Observations	
D. Stramski	Refinement, Evaluation, and Application of an Improved POC Ocean Color Product for Continuity of Climate Data Records	
F. Wentz	Improved Air Sea Essential Climate Variables (AS-ECV) from AQUA AMSR-E and S-NPP VIIRS	
J. Werdell	Advancing the Retrieval of Marine Inherent Optical Properties from Mult-Sensor, Multi-Spectral Satellite Ocean Color Radiometry	

Understanding airborne fertilization of oceanic ecosystems using satellite products

L.A. Remer, Yingxi Rona Shi, Toby Westbury, M. Behrenfeld, Hongbin Yu



- Distinct difference chlorophyll (Chl) in the 2 populations.
- But no increase in biomass (Cphyto).
- Differences seen in physiological responses (Chl:C and FLHcorr).

Caribbean: 10 to 15N -70 to -60W; 2003 to 2016.

Ocean parameters from MODIS Aqua

Dust deposition calculated from MERRA-2 using flux divergence method.

Analysis of simultaneous aerosol and ocean glint retrieval using multiangle observations

K. Knobelspiesse, A. Ibrahim, Z. Ahmad, S. Bailey, B. Franz, J. Gales, M. Gao, M. Garay, R. Levy, S. Anderson, O. Kalashnikova, GSFC & JPL

We found the best parameter set with a Bayesian inference-based sensitivity study

Using the radiative transfer code used to build lookup table's (LUT) in OBPG, we found four parameters represent MISR scenes well.

Manuscript under review at *Atmospheric Measurement Techniques*

Analysis of simultaneous aerosol and ocean glint retrieval using multi-angle observations

Kirk Knobelspiesse[1], **Amir Ibrahim**[1,2], **Bryan Franz**[1], **Sean Bailey**[1], **Robert Levy**[1], **Ziauddin Ahmad**[1,3], **Joel Gales**[1,3], **Meng Gao**[1,2], **Michael Garay**[4], **Samuel Anderson**[1,2], **and Olga Kalashnikova**[4]

[1]NASA Goddard Space Flight Center, Greenbelt, MD, USA
[2]Science Systems and Applications, Inc., Lanham, MD, USA
[3]Science Applications International Corp., Greenbelt, MD, USA
[4]JPL, California Institute of Technology, Pasadena, USA

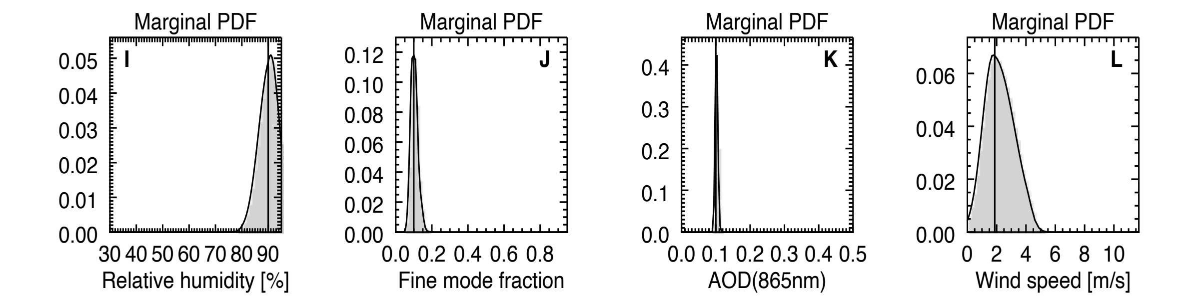
Correspondence: Kirk Knobelspiesse (Kirk.Knobelspiesse@nasa.gov)

Abstract.
Since early 2000, NASA's Multi-angle Imaging SpectroRadiometer (MISR) instrument has been performing remote sensing retrievals of aerosol optical properties from the polar orbiting Terra spacecraft. A noteworthy aspect of MISR observations over the ocean is that, for much of the Earth, some of the multi-angle views have contributions from solar reflection by the ocean surface (glint, or glitter), while others do not. Aerosol retrieval algorithms often discard these glint influenced observations because they can overwhelm the signal and are difficult to predict without knowledge of the (wind speed driven) ocean surface roughness. Other algorithms directly use the sun glint to determine the ocean surface roughness, and by extension wind speed, but may not simultaneously retrieve aerosol optical properties. However, theoretical studies have shown that multi-angle observations of a location at geometries with and without reflected sun glint can be a rich source of information, sufficient to support simultaneous retrieval of both the aerosol state and the wind speed at the ocean surface.

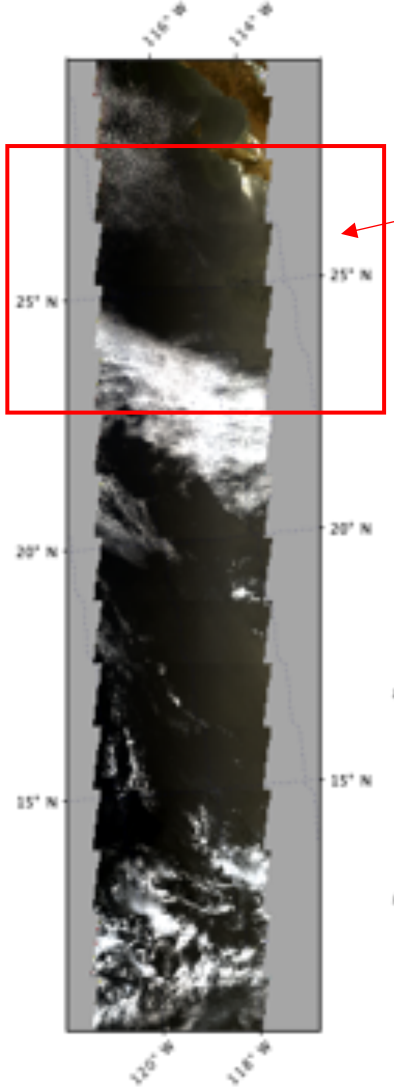
We are in the early stages of creating such an algorithm. In this manuscript, we describe our assessment of the appropriate level of parameterization for simultaneous aerosol and ocean surface property retrievals using sun glint. For this purpose, we use Generalized Nonlinear Retrieval Analysis (GENRA), an information content assessment (ICA) technique employing Bayesian inference, and simulations from the Ahmad-Fraser iterative radiative transfer code. We find that a suitable parameterization for the retrieval algorithm includes four parameters: aerosol optical depth (τ, which is the atmospheric column aerosol optical extinction), particle size distribution (expressed as the relative contribution of small particles in a bimodal size distribution, or fine mode fraction, f), surface wind speed (w, scalar/non directional) and relative humidity (r, as a means to define the aerosol water content and complex refractive index). None of these parameters define ocean optical properties, as we found that the aerosol state could be retrieved with the nine MISR near-infrared views alone, where the ocean body is black in the open ocean. We also found that retrieval capability varies with observation geometry, and that as τ increases so does the ability to determine aerosol intensive optical properties (r and f, while it decreases for w). Increases in w decrease the ability to determine the true value of that parameter, but have minimal impact on retrieval of aerosol properties. We explored the benefit of excluding the two most extreme MISR view angles (view zenith angles of 70.5° fore and aft of nadir), which may be subject to inaccurate radiative transfer calculations for models that make plane parallel approximations. So long as the retrieval algorithm accounts for increased uncertainty due to this for those view angles, it is best to use all nine views. Finally, the impact of treating wind speed as a scalar parameter, rather than as a two parameter directional wind, was tested. While the simpler scalar model does contribute to overall aerosol uncertainty, it is not sufficiently large to justify the addition of another dimension to parameter space.

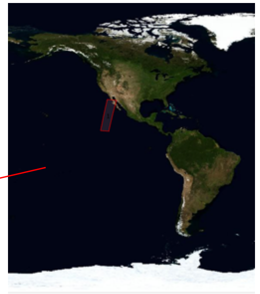
The long term goal of this project is to use the aerosol retrieval from MISR to perform an atmospheric correction for coincident ocean color (OC) observations by the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument, also on the NASA Terra spacecraft. Unlike MISR, MODIS is a single view angle instrument, but it has a more

Bayesian inference tests on retrieval LUT provides posterior PDF for each LUT 'node'. One example:



Early results with test algorithm look promising
This for MISR only, next step apply to MODIS

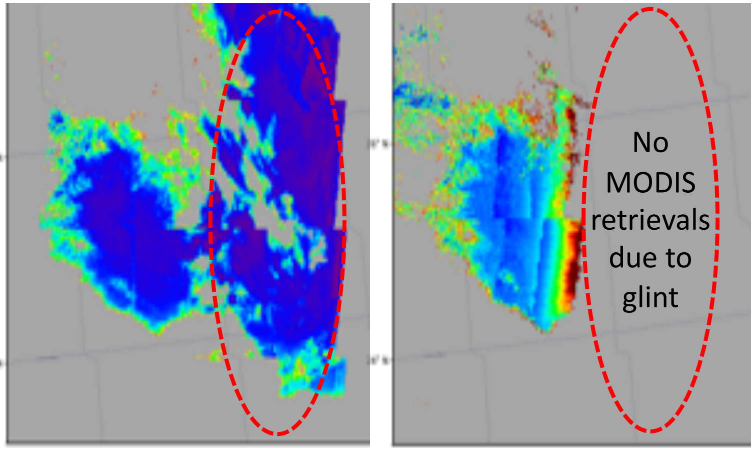




MISR retrievals work where MODIS OC standard processing doesn't

AOT(865) - MISR

AOT(869) - MODIST



Ocean SIPS - Ocean Color Processing Status

R2018.0 Completed

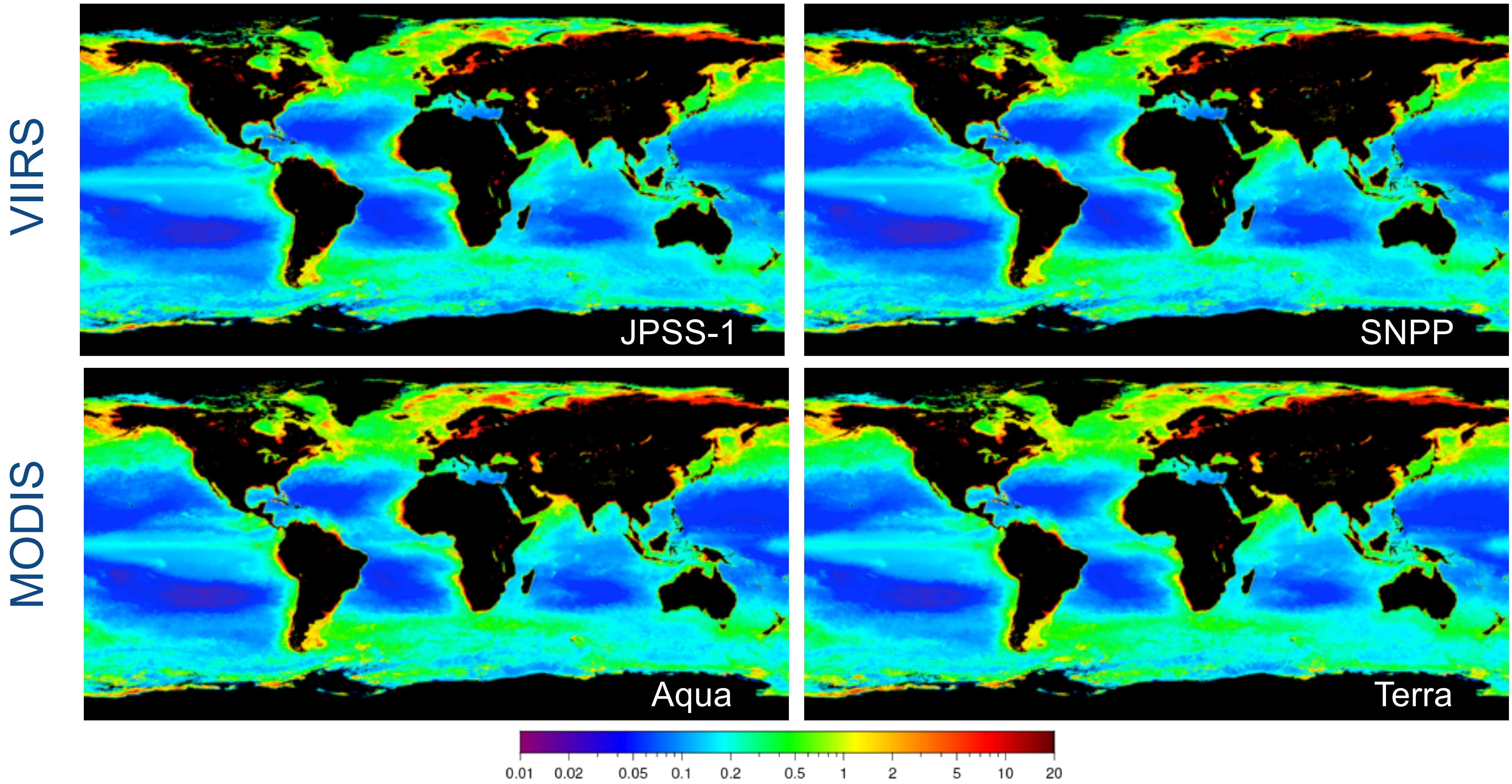
- VIIRS/SNPP (Dec 2017), MODIS/Aqua (Jan 2018), MODIS/Terra (April 2018), and **VIIRS/JPSS1** (Sep 2018)

Purpose

- incorporate updates to vicarious calibration due to revised MOBY time-series
- incorporate updates to instrument calibration
- no algorithm changes since R2014.0
- **first processing for VIIRS on JPSS-1**

JPSS-1 VIIRS has been fully integrated into the current ocean color processing (R2018.0) and OBPG product validation system. Vicarious cal to SNPP, no temporal cal.

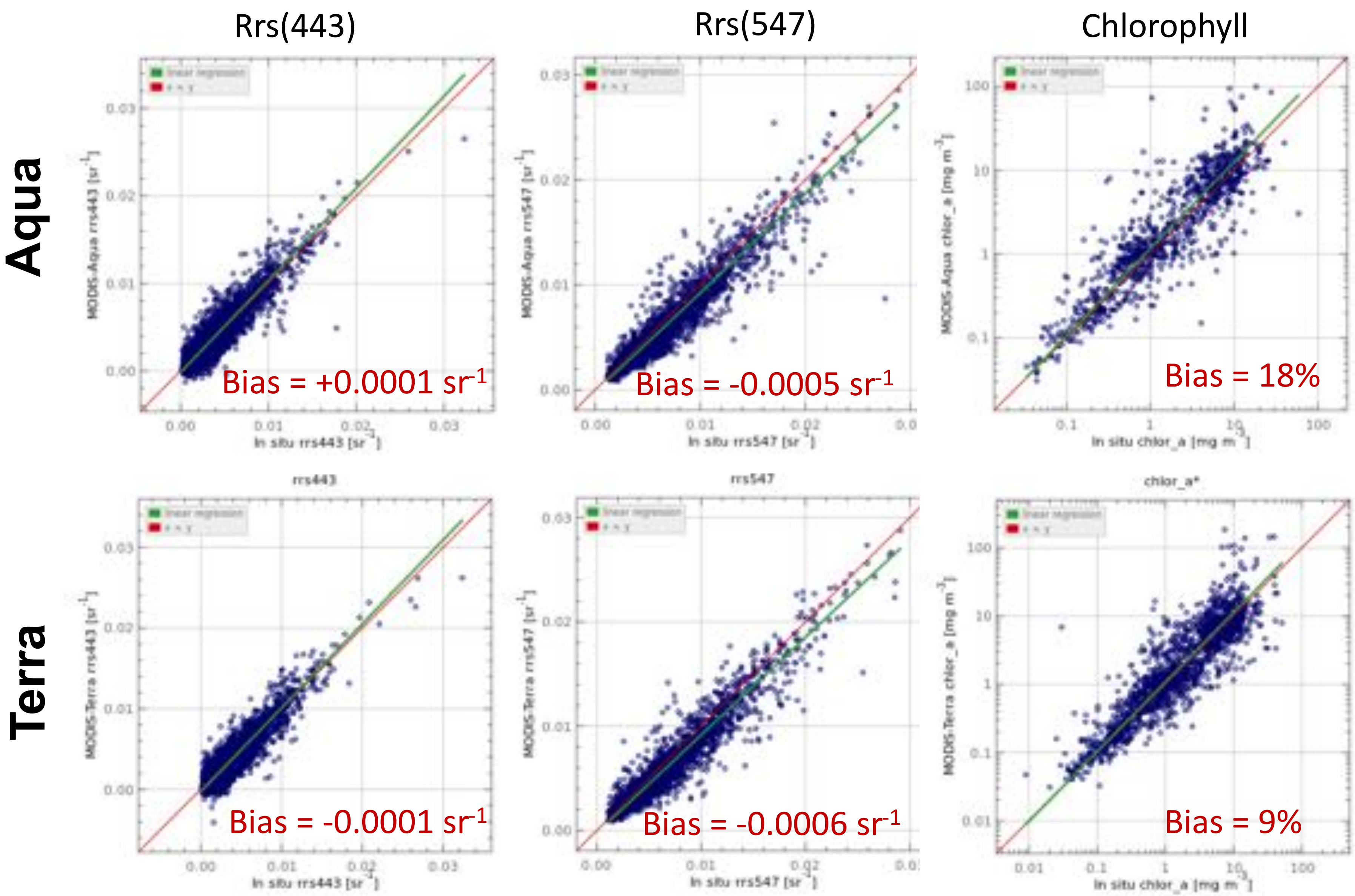
Annual Mean Chlorophyll Concentration for 2018



MODIS R2018.0 Validation

Match-ups to SeaBASS and AERONET-OC

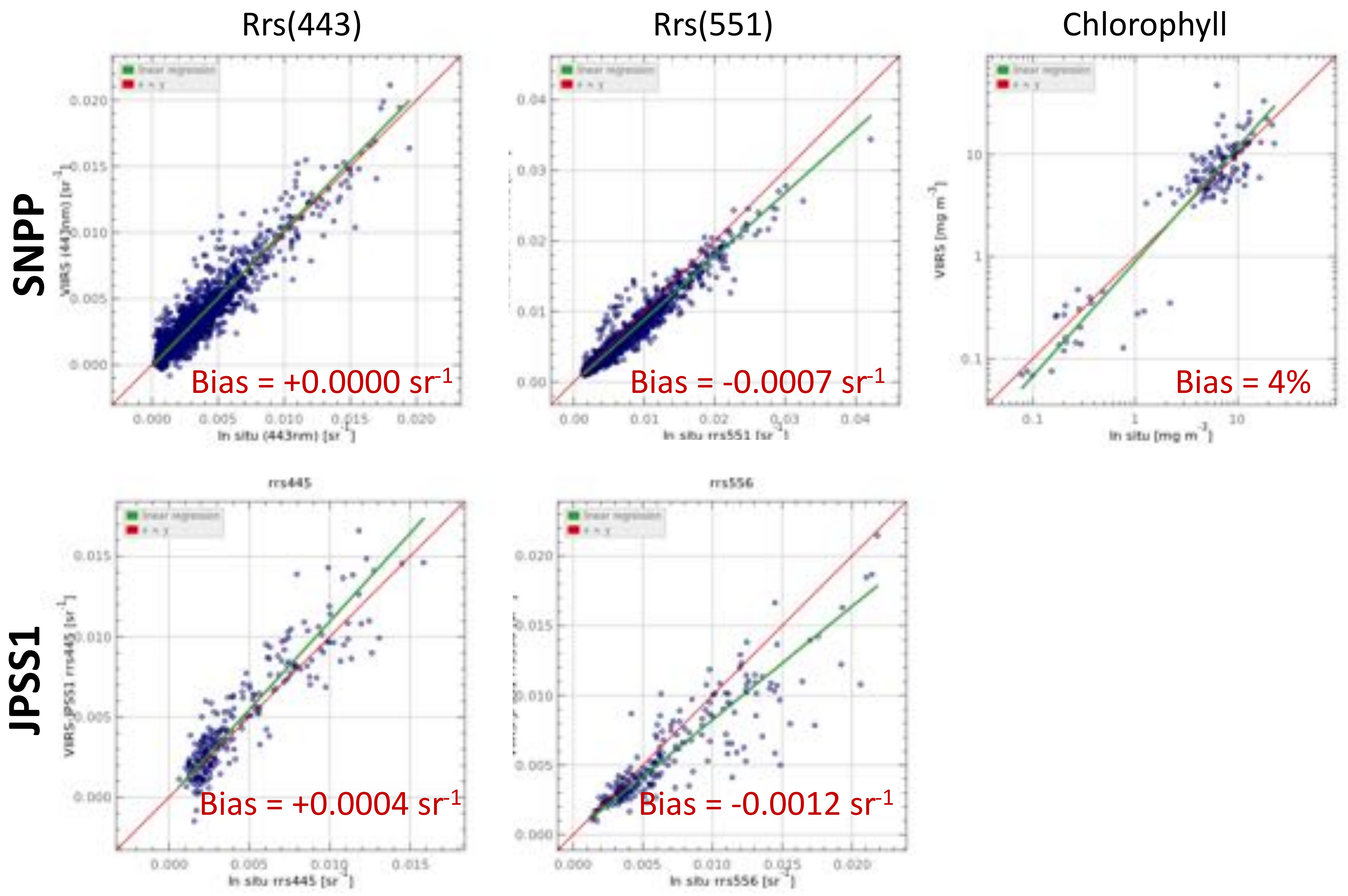
- MODIS Rrs and Chl from Aqua and Terra in good agreement with in situ
- Mean bias in Rrs remains near zero



VIIRS R2018.0 Validation

Match-ups to SeaBASS and AERONET-OC

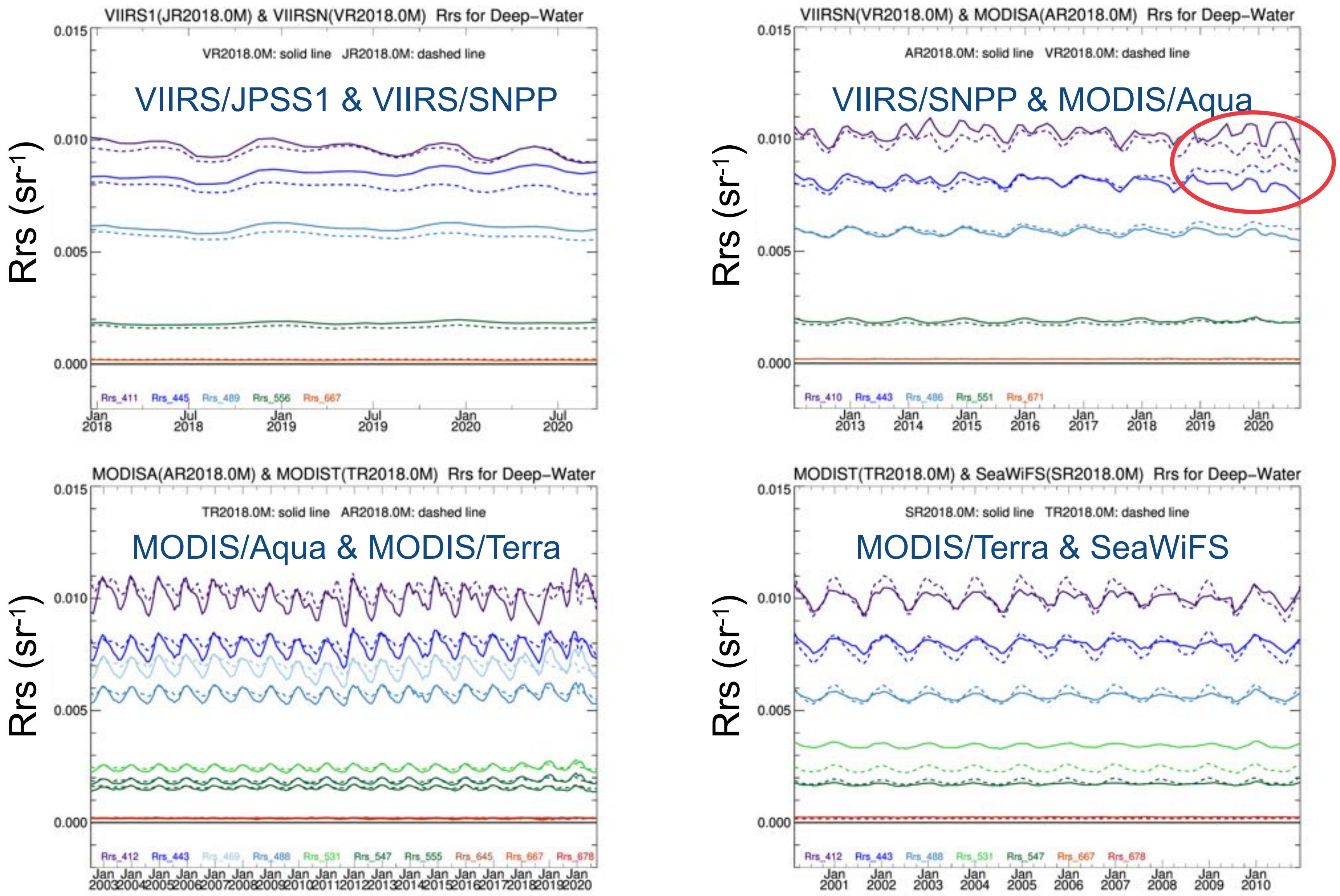
- VIIRS/SNPP Rrs and Chlorophyll in very good agreement with in situ
- VIIRS/JPSS1 Rrs in good agreement, but with larger differences based on limited match-ups



Global Deep-Water Rrs Trends

Comparison trends over common mission lifetime

- VIIRS/SNPP shows bias and trends in blue relative to MODIS/Aqua and VIIRS/JPSS1
- SeaWiFS, MODIS/Aqua, and MODIS/Terra show good agreement.



VIIRS/SNPP Calibration Update

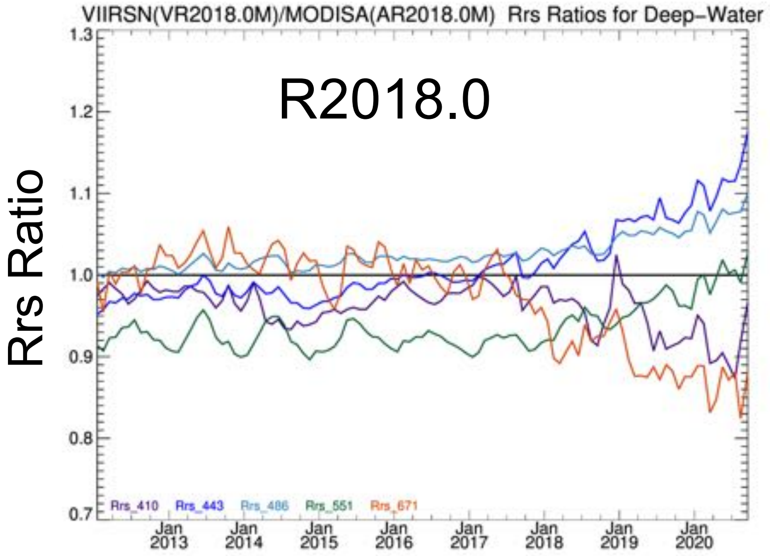
Calibration Changes for Next Reprocessing

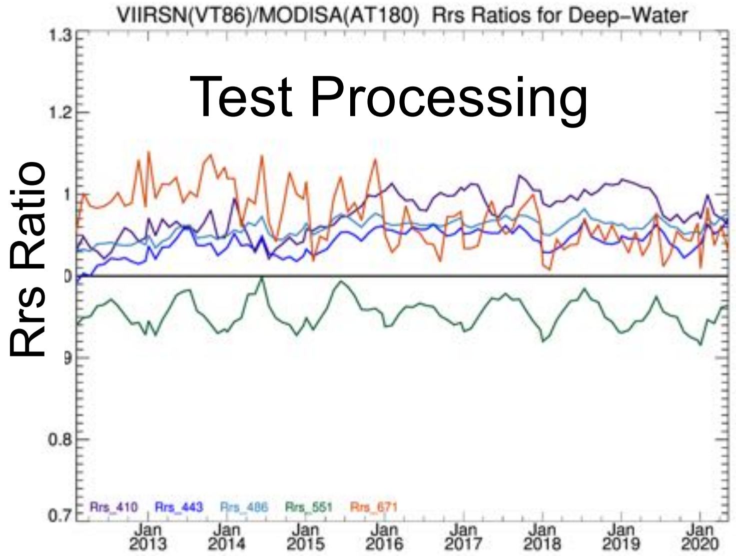
- extension of lunar/solar time-series with new measurements
- revised model for temporal fit to lunar time-series (exponential in time + linear with libration), used to correct the solar time-series
- no lunar correction applied to M5,6,7 (no detectable trend)
- temporal gain adjustments for impact of modulated RSRs on ocean/atmosphere signal, for bands M1-M7

Impact to Rrs Timeseries

- reduces trends in blue relative to MODIS/Aqua (and J1 VIIRS)
- suspect trends reduced, biases increased (vicarious cal issue?)
- testing/refinements on-going in preparation for reprocessing

VIIRS/SNPP & MODIS/Aqua





Ocean SIPS - Next OC Reprocessing

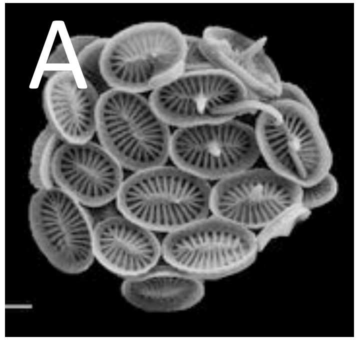
Planning for ~~Spring 2020,~~ first major update of algorithms since R2014.0

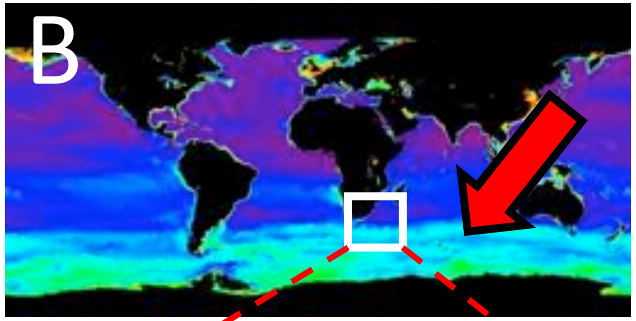
1. updates to ancillary data sources
   - from NCEP/TOMS-OMI/etc. to MERRA-2 assimilation product
2. updates to atmospheric correction methods and tables
   - multi-scattering aerosol selection, improved gas corrections (H2O), bug in Rayleigh tables at extreme solar zenith, error propagation
3. updates to pure seawater optical properties (nw, aw, bbw)
   - apply temperature & salinity dependence (e.g., Werdell et al. 2013), bug in pure-water aw/bbw (off by few nm)
4. updates to masks and flags
   - reduced straylight masking (Hu et al. 2019, JGRO), absorbing aerosol flag based on MERRA-2 transport model
5. updates to derived product algorithms
   - chlor-a coefficient update (Hu et al. 2019, JGRO; O'Reilly and Werdell 2019),
6. new products
   - Rrs uncertainties (TBD), new standard products (TBD)

CHL algorithm refinements
PIC updates, bb*
POC algorithm refinement

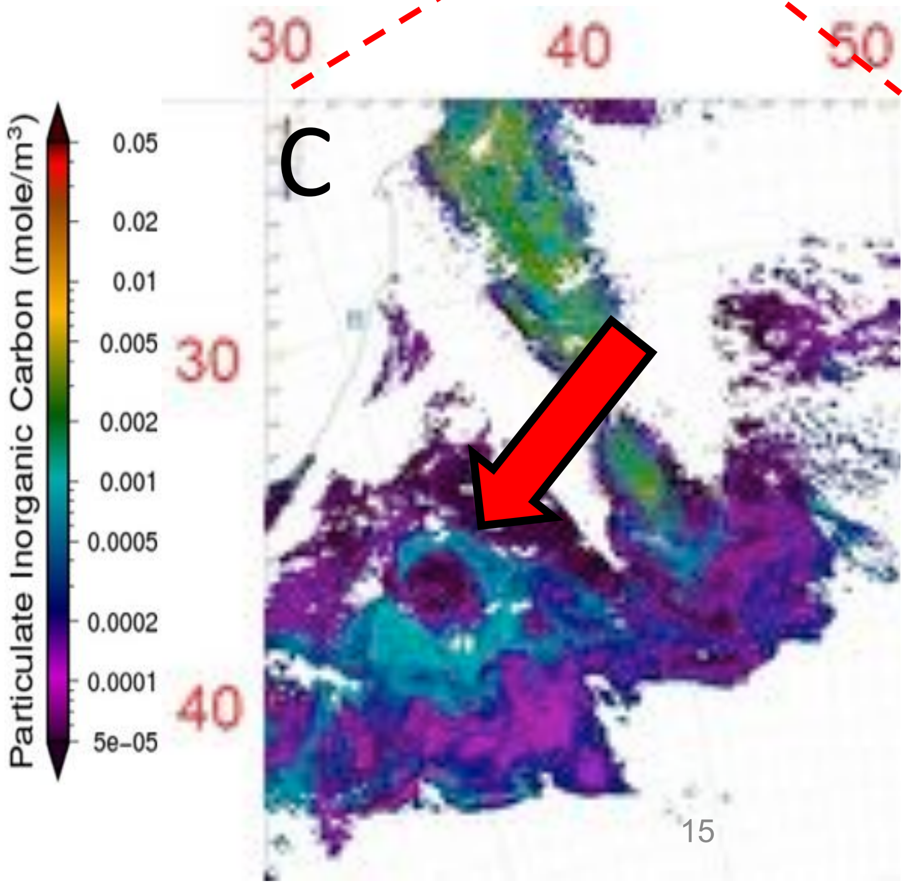
Particulate Inorganic Carbon Product Maintenance for MODIS and Suomi-NPP

William M. Balch, Bigelow Laboratory for Ocean Sciences, East Boothbay, ME





- 2-band/3-band PIC algorithm used to document ocean features containing coccolithophores (A) , growing in the Great Calcite Belt (B)
- These ocean features (C) entrap cocco-rich water for months, facilitating the study of how coccolithophores "condition" the ocean.
- Using real-time NPP & MODIS Aqua imagery to navigate research vessels to PIC-rich features (C). Provides critical new validation data for the 2B/3B PIC algorithm.
- Part of a broader NSF study of the conditioning of Sub-Antarctic Mode Water (SAMW) by coccolithophores which can affect phytoplankton species composition and productivity as far away as the northern hemisphere (>40y later).

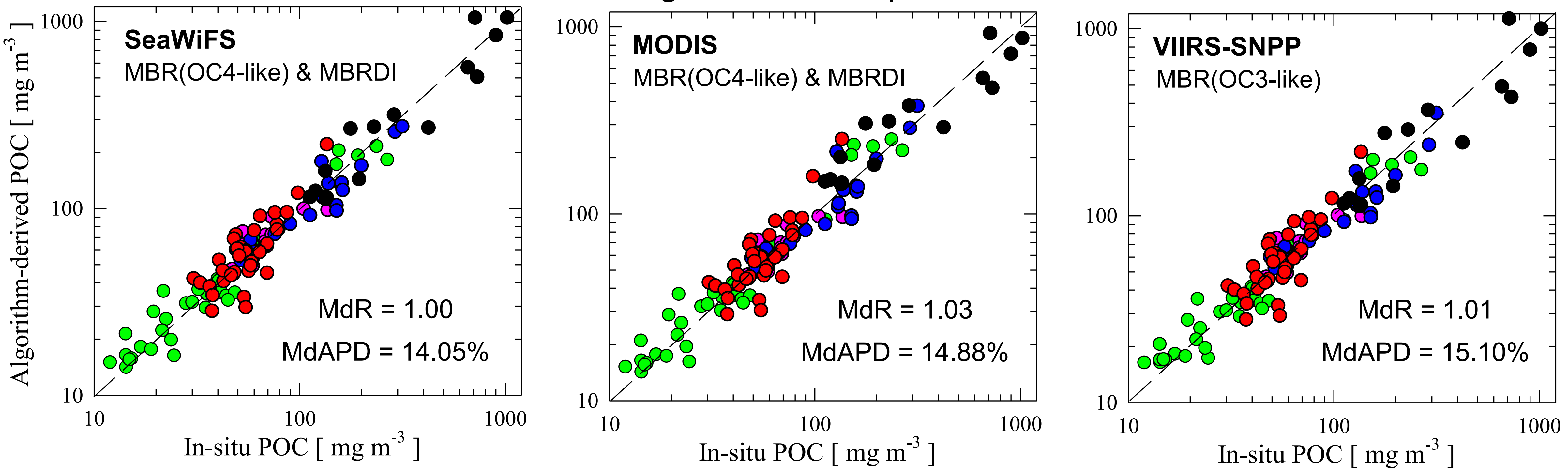


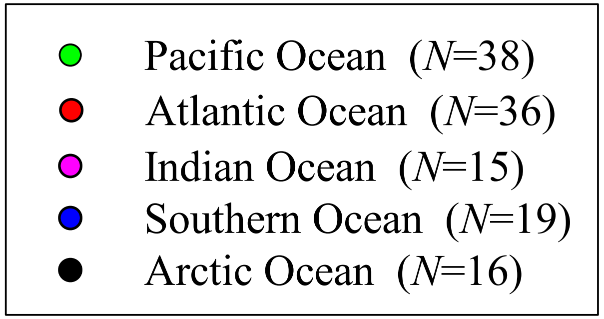
Bigelow | Laboratory for Ocean Sciences

Particulate Organic Carbon Algorithm Development & Refinement

D. Stramski, R. Reynolds, I. Joshi, D. Robinson

derived vs. measured POC for the algorithm development dataset



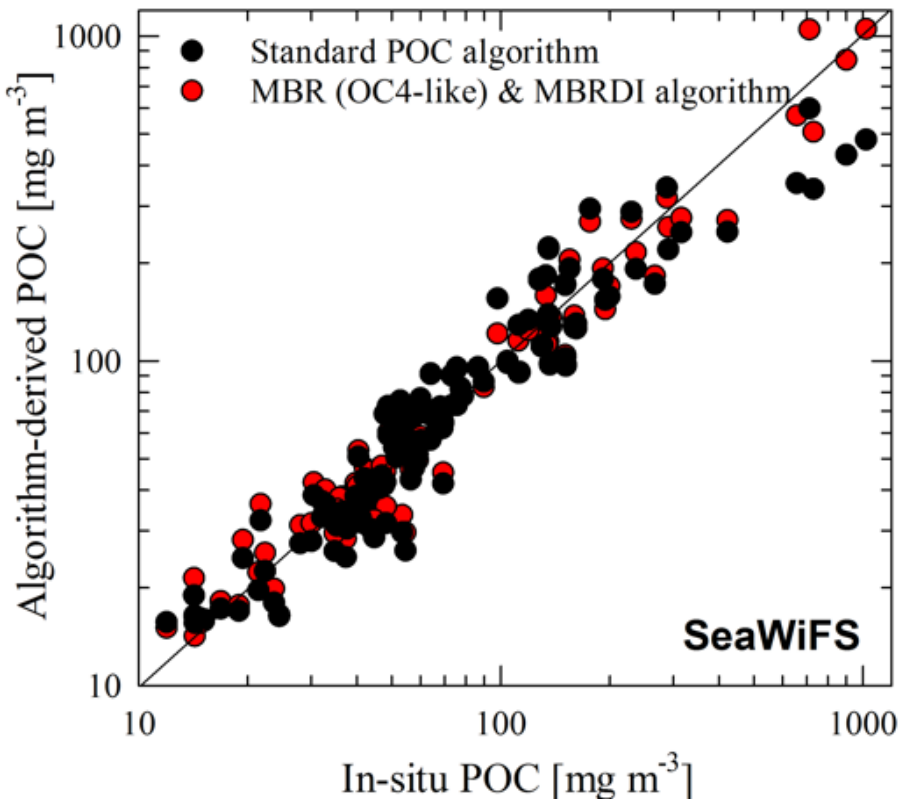


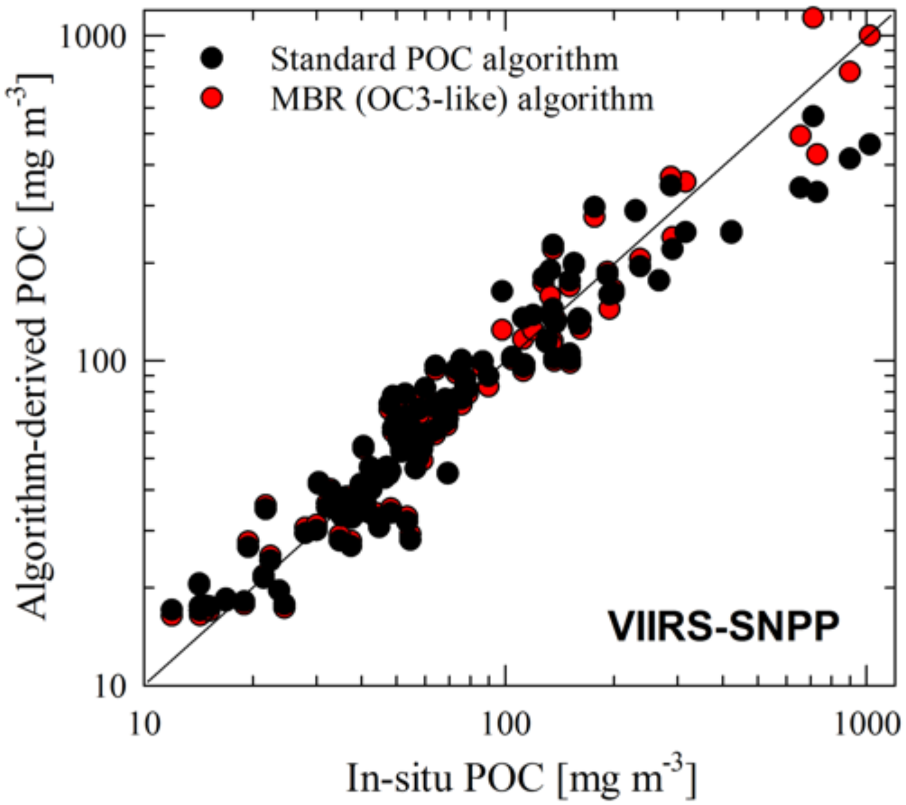
MdR - Median Ratio of algorithm-derived to measured POC

MdAPD - Median Absolute Percent Difference between algorithm-derived and measured POC

Ongoing work on algorithm performance: Validation with independent in-situ datasets and satellite matchups

Comparison of standard and new POC algorithms for SeaWiFS and VIIRS for the algorithm development dataset





Standard algorithm	New algorithm	Standard algorithm	New algorithm
MdR = 0.95	MdR = 1.00	MdR = 1.01	MdR = 1.01
MdAPD = 18.11%	MdAPD = 14.05%	MdAPD = 17.32%	MdAPD = 15.10%

Ocean SIPS - SST Reprocessing(s) Completed

VIIRS/SNPP

- MODIS continuity algorithm (PI Minnett, not reselected)
- **R2016.0** (Mid 2016) – first processing of SST for VIIRS, new quality flag based on alternating decision trees, VIIRS-specific algorithm coefficient and error tables.
- **R2016.1** (Jul 2018) – updated SSES tables, revised ice masking, minor fixes (changes only implemented for forward-stream).
- **R2016.2 (Nov 2019**) – new reference SST (GHRSST L4 CMC)

MODIS (Aqua and Terra)

- **R2019.0 (Jan 2020)** – incorporates algorithm changes associated with VIIRS R2016.x, adds dust correction, updates to algorithm coefficient and error tables

Reprocessing of SNPP/VIIRS complete, with algorithm updates developed in previous Science Team cycle. Reprocessing of MODIS complete, consistent with algorithm refinements developed for VIIRS. No JPSS1 VIIRS SST is being produced.

MODIS SST R2019.0 Algorithm Improvements

P. Minnett & K. Kilpatrick

- Improved cloud-screening – Alternating Decision Trees.

  Kilpatrick, K.A., Podestá, G., Williams, E., Walsh, S., & Minnett, P.J. (2019). Alternating Decision Trees for Cloud Masking in MODIS and VIIRS NASA Sea Surface Temperature Products. *Journal of Atmospheric and Oceanic Technology 36*, 387-407. 10.1175/jtech-d-18-0103.1

- Desert dust aerosol atmospheric corrections.

  Luo, B., Minnett, P.J., Gentemann, C., & Szczodrak, G. (2019). Improving satellite retrieved night-time infrared sea surface temperatures in aerosol contaminated regions. *Remote Sensing of Environment 223*, 8-20. https://doi.org/10.1016/j.rse.2019.01.009

- Better high latitude atmospheric corrections.

  Jia, C. & Minnett, P.J. (2020). Satellite Infrared Retrievals of Sea Surface Temperature at High Latitudes. *Remote Sensing of Environment. 251*, 112094. https://doi.org/10.1016/j.rse.2020.112094.

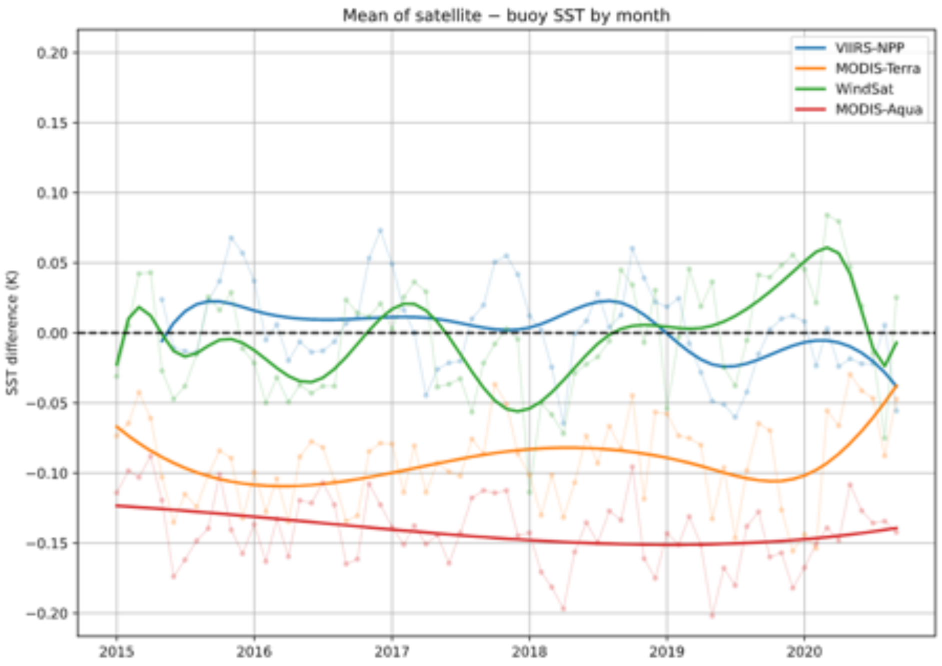
- Improved discrimination of cloud and sea ice.

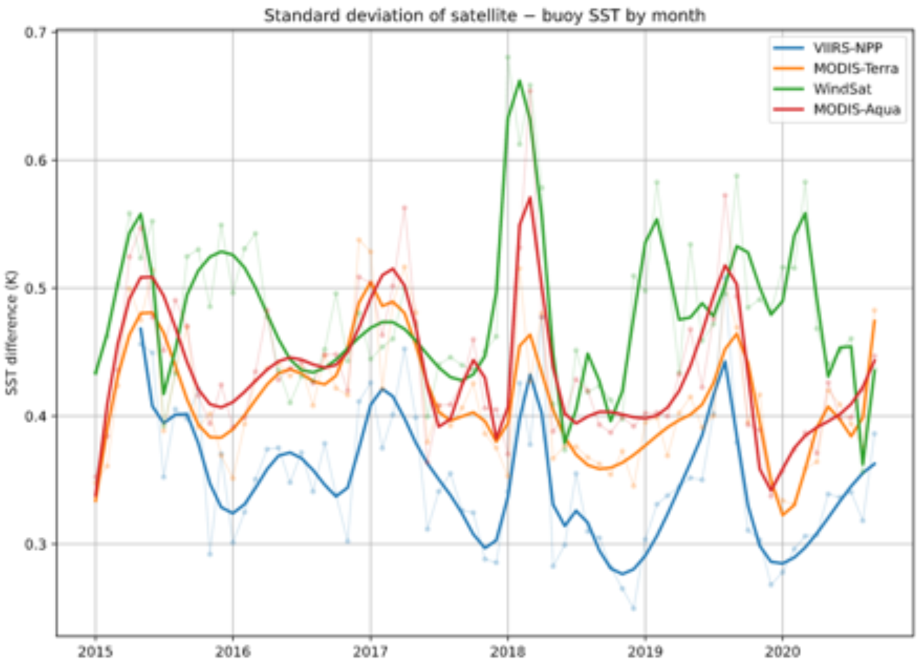
- Additional terms in the 11-12 µm NLSST atmospheric correction algorithm to improve accuracy towards the edges of the swaths through long atmospheric paths.

- Replace “Reynolds” SSTs by Canadian Meteorology Center daily SST fields as T_{ref}.

MODIS/VIIRS SST comparison to buoy SST

F. Wentz & R. Lindsley





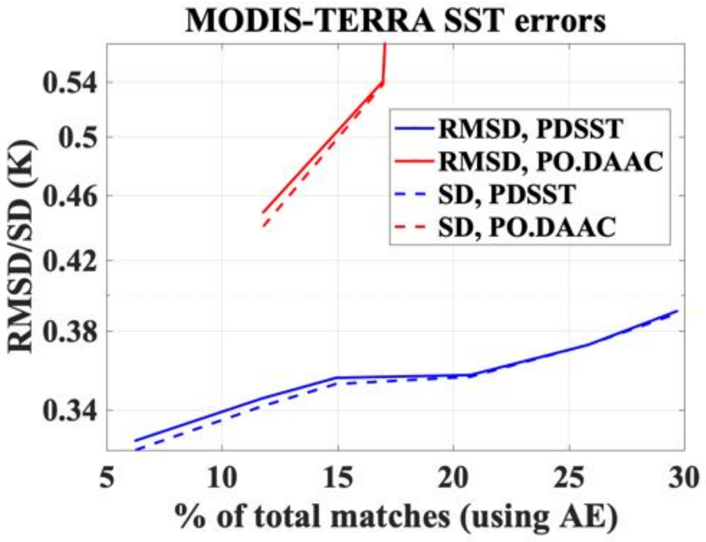
Sensor	Count	Mean (K)	Std. (K)
WindSat	2479103	-0.03	0.53
MODIS-Terra	1791472	-0.11	0.44
MODIS-Aqua	1700872	-0.13	0.45
VIIRS-SNPP	1124642	0.01	0.36

VIIRS on SNPP showing best quality (lowest bias and std) relative to buoy match-ups.

Physical deterministic sea surface temperature from MODIS radiances

P. Koner

- PDSST suite is combination of the SST retrieval using transformative approach and cloud detection using radiative transfer model (CRTM).
- Research showed 3-4 times information gain as compared to the regression based operational MODIS-AQUA SST product for the nighttime and daytime.
- PDSST suite is applied to MODIS-TERRA radiance recently. Several months of matchups with in-situ are studied and the results are alike to the same from MODIS-AQUA. For demonstration, a month of matchups of October 2019 are shown below: (RMSD = root mean squared difference from in-situ)

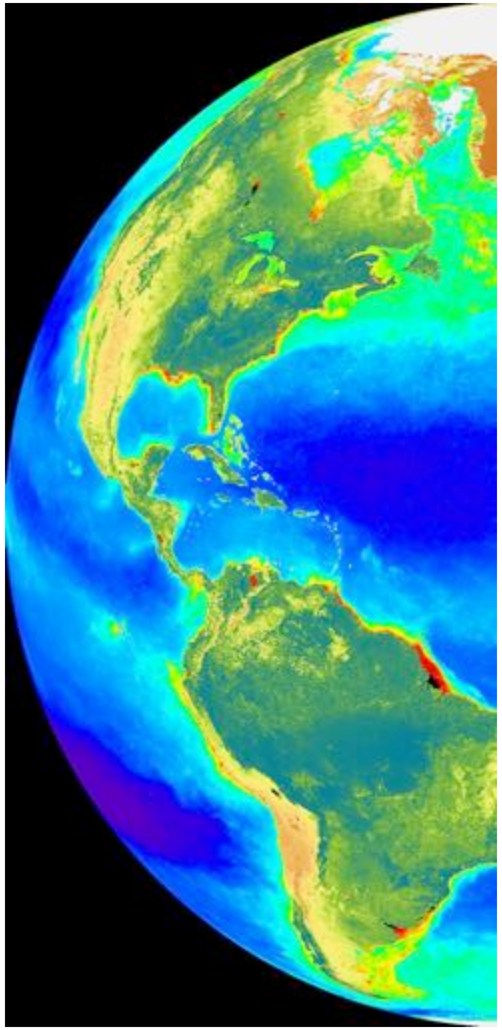


Publications (2020):

1. P. K. Koner, Daytime Sea Surface Temperature Retrieval Incorporating Mid-Wave Imager Measurements: Algorithm Development and Validation, Accepted in IEEE Trans. Geosci. Remote Sens., 2020. Early Access Online.
2. P. K. Koner, A transformative approach to enhance the parameter information from microwave and infrared remote sensing measurements, Big Earth Data 2020, 4(3), 322-347.
3. P. K. Koner, Enhancing Information Content in the Satellite-Derived Daytime Infrared Sea Surface Temperature Dataset Using a Transformative Approach, Front. Mar. Sci. 7:556626, 2020.

Ocean SIPS implementation in progress – toward provisional product

Summary



- Science team proposal work is progressing well in both science output and algorithm maintenance and refinement, with modest reduction in productivity due to COVID-19.
- MODIS & SNPP VIIRS standard SST products were reprocessed in 2019-2020, with a wide range of algorithm improvements incorporated.
- R2018.0 ocean color product quality remains good overall, temporal trends from VIIRS on JPSS1 appear stable, but VIIRS on SNPP showing late mission trends that need to be corrected.
- Next multi-mission ocean color reprocessing now planned for 2021, to incorporate calibration updates and a host of algorithm refinements.

Questions?

In situ Rrs Match-up Statistics

field data from AERONET-OC and SeaBASS

λ (nm)	Mean Bias (sr^{-1})		MAE (sr^{-1})	
	Aqua	Terra	Aqua	Terra
412	0.00001	-0.00031	0.00102	0.00106
443	0.00005	-0.00014	0.00077	0.00079
488	-0.00054	-0.00053	0.00079	0.00078
531	-0.00055	-0.00053	0.00078	0.00076
547	-0.00050	-0.00055	0.00078	0.00079
555	-0.00079	-0.00080	0.00094	0.00094
667	-0.00017	-0.00018	0.00029	0.00030
678	-0.00016	-0.00019	0.00033	0.00036

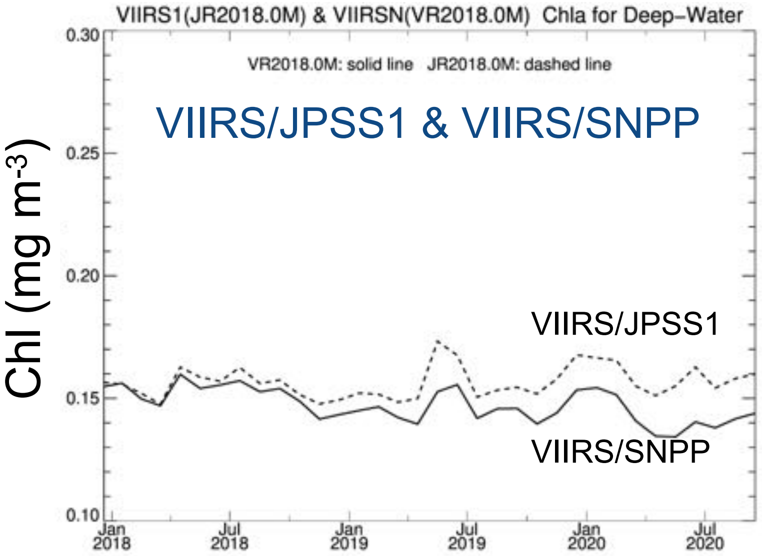
λ (nm)	Mean Bias (sr^{-1})		MAE (sr^{-1})	
	JPSS1	SNPP	JPSS1	SNPP
410	-0.00072	-0.00036	0.00130	0.00105
443	0.00041	0.00002	0.00110	0.00077
486	-0.00062	-0.00063	0.00108	0.00088
556(1)	-0.00115	-0.00071	0.00150	0.00088
671	-0.00034	-0.00020	0.00050	0.00029

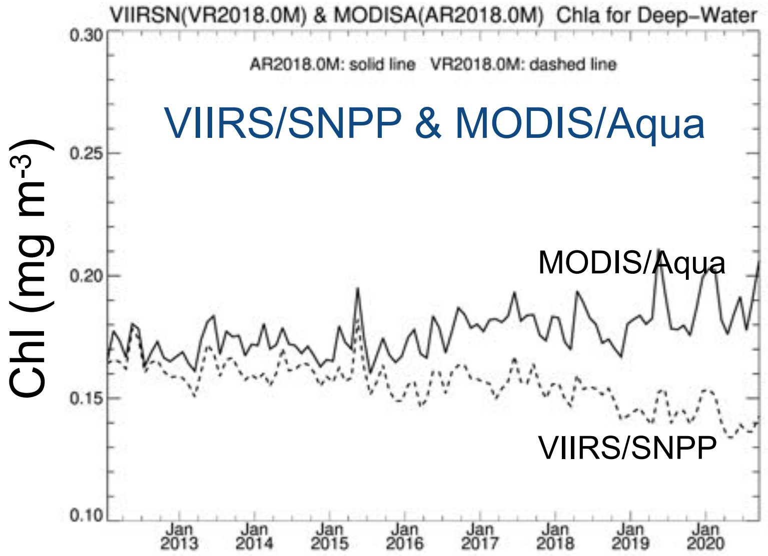
- MODIS (Aqua & Terra) and VIIRS/SNPP show very similar agreement with in situ measurements
- MODIS/Terra does shows larger biases in blue bands relative to MODIS/Aqua
- VIIRS/JPSS1 shows larger Mean Bias and MAE, based on limited match-ups, with no temporal calibration and no vicarious cal to MOBY

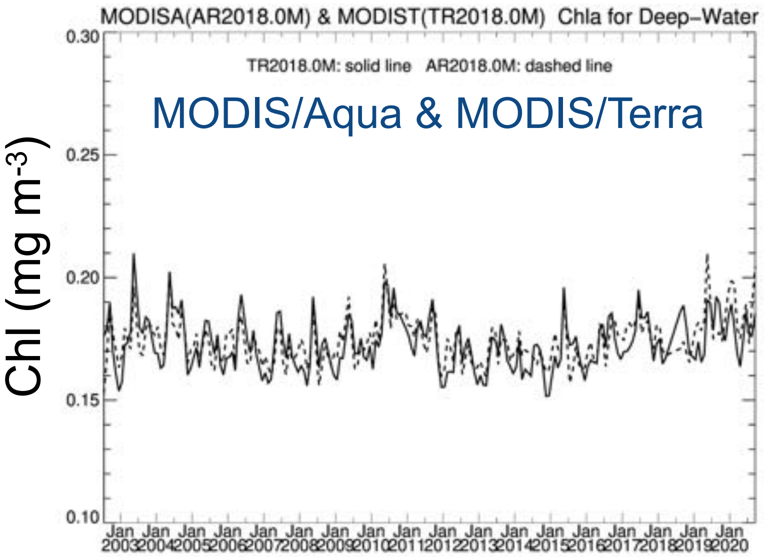
Global Deep-Water Chlorophyll Trends

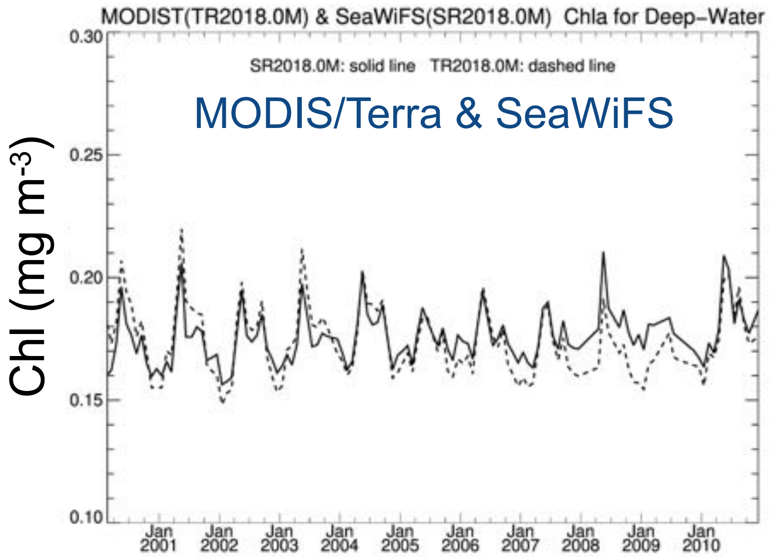
Comparison trends over common mission lifetime

- VIIRS/SNPP shows negative trend relative to VIIRS/JPSS1 & MODIS/Aqua
- SeaWiFS, MODIS/Terra, MODIS/Aqua in good agreement, with short-term deviations









RETRIEVAL OF THE PARTICLE SIZE DISTRIBUTION USING COATED SPHERES MODELING

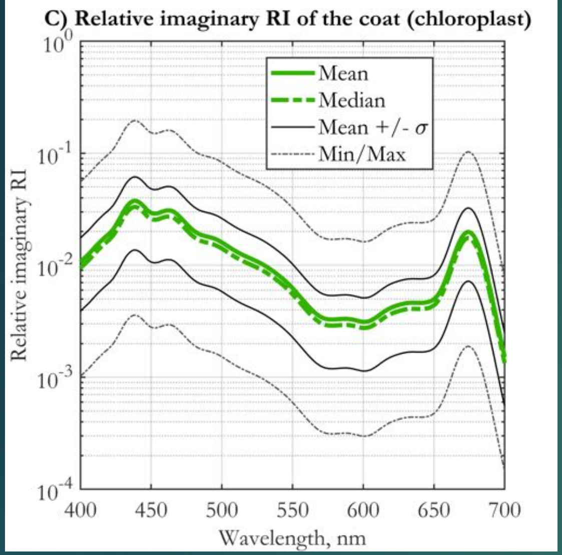


Fig. 1

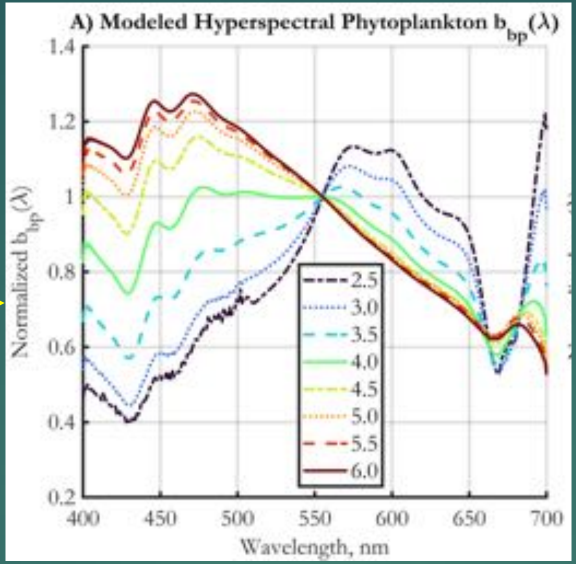


Fig. 2

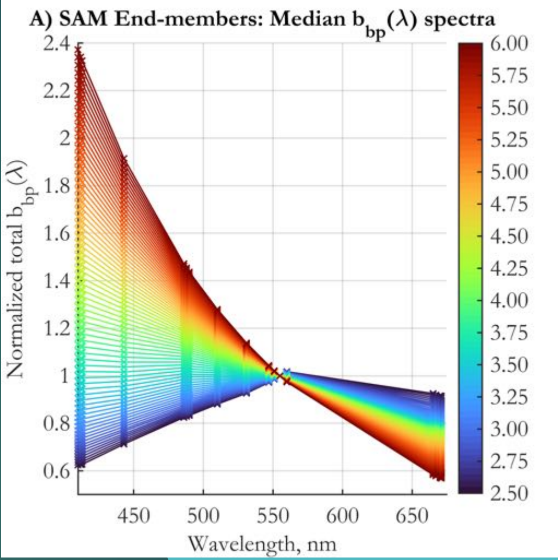


Fig. 3

- The Equivalent Algal Populations (EAP) model (Bernard et al., 2009; Robertson-Lain et al., 2018) was used to construct inputs (example in Fig. 1) to a coated spheres Mie scattering model.
- Hyperspectral backscattering was modeled for EAP-based coated phytoplankton (Fig. 2) + separately homogeneous NAP and was used to construct end-members for a Spectral Angle Mapping (SAM) algorithm (Fig. 3).
- The SAM algorithm was used to retrieve the PSD from a sample OC-CCI merged image – PSD slope for May 2004 is shown in Fig. 4. The Loisel and Stramski (2000) IOP algorithm was used to get $b_{bp}(\lambda)$.

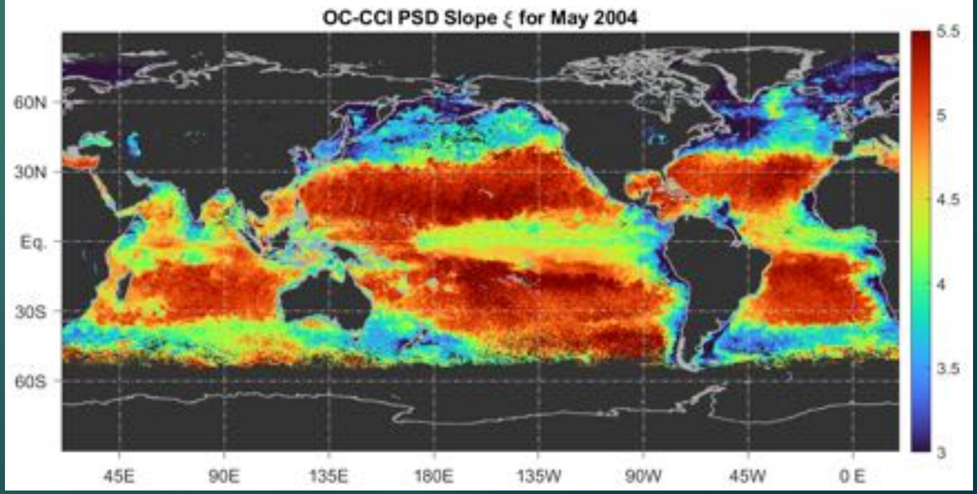


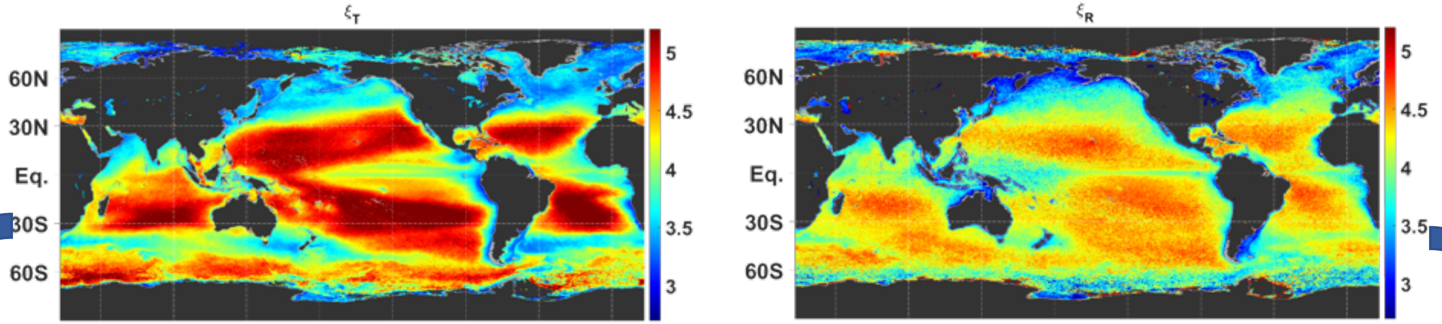
Fig. 4

TIHOMIR S. KOSTADINOV AND COLLABORATORS, NOV. 2020

NASA GRANT #80NSSC19K0297

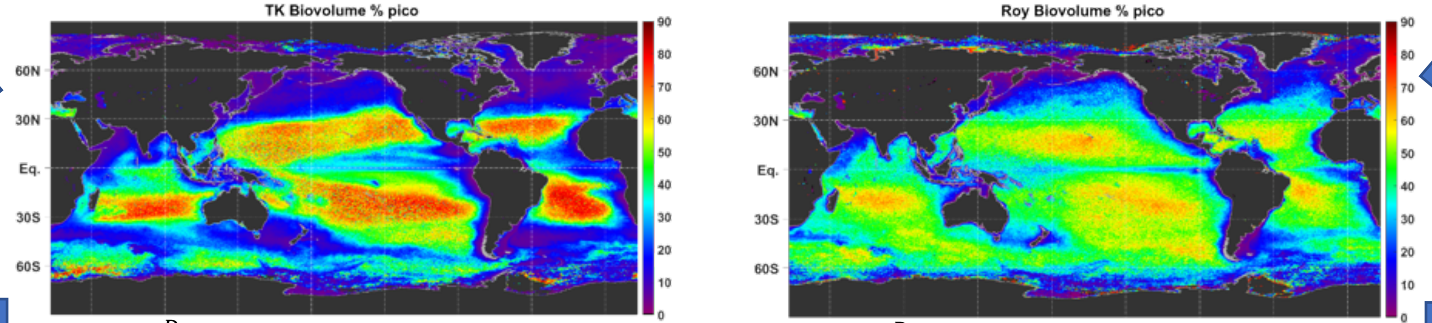
Backscattering Based Algorithm | Absorption Based Algorithm

PSD slopes



PSD slopes result in differences in relative input of size groups

% phytoC in pico



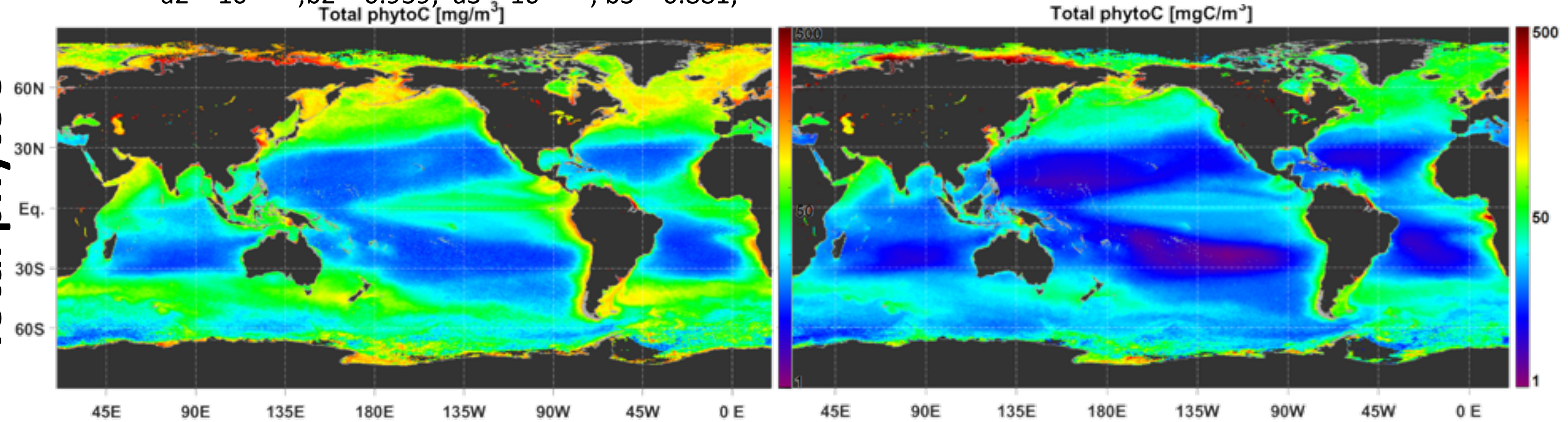
$$C_T = \frac{1}{3}\int_{D_{min}}^{D_{max}} \left(N_o\left(\frac{D}{D_o}\right)^{-\xi_T}\right)\left[10^{-9}a\left(10^{18}\frac{\pi}{6}D^3\right)^b\right]dD$$

A set of coefficients is used: $a1 = 10^{-0.583}$; b1 = 0.860; $a2 = 10^{-0.665}$; b2 = 0.939; $a3 = 10^{-0.933}$; b3 = 0.881;

$$C_R = \int_{D_{min}}^{D_{max}} \left(kD^{-\xi_R}\right)\left[10^{-9}a\left(10^{18}\frac{\pi}{6}D^3\right)^b\right]dD$$

Coefficients: a = 0.54; b = 0.86

Total phytoC



We compare derived phytoplankton C biomass in 3 size groups (pico (0.5 - 2 μm), nano (2- 20 μm) and micro (20 - 50 μm)), for 2 products: Kostadinov et al., 2016 (Backscattering based) and Roy et al., 2017 (absorption based) with SeaWIFS 2003-2007. We also analyze in detail seasonality patterns.

Goal = understand the implications of the very different underlying assumptions for resulting plankton patterns.

Assumptions:

- phytoplankton cells are spherical;
- absorption algorithm accounts for in-vivo phytoplankton, while backscattering registers all particles
- allometric coefficients are derived from Menden-Deuer & Lessard,2000, but also different.

Team: E. Kochetkova, I.Marinov, T.Kostadinov, Shovonlal Roy

Nasa grant #80NSSC19K0297

Refinement of Ocean Color Algorithms for Estimating Particulate Organic Carbon (POC) Concentration in Surface Ocean Waters

Dariusz Stramski (PI)
Rick A. Reynolds (Co-I)
Ishan Joshi (Postdoc)

Dale Robinson (Co-I)

MODIS/VIIRS Science Team Meeting
19 November 2020

Primary objectives and tasks

(1) Refine or develop new instrument-specific algorithms for deriving a standard global POC product from ocean color observations with SeaWiFS, MODIS, VIIRS, MERIS, and OLCI sensors ***(Tasks completed)***.

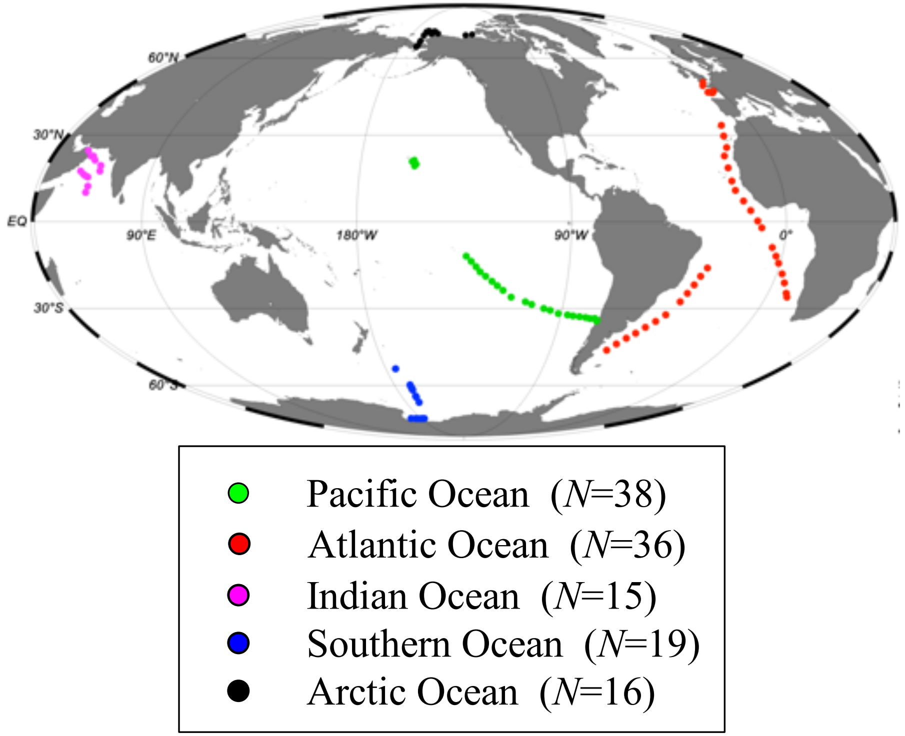
(2) Evaluate/validate the performance of refined/new algorithms and quantify uncertainties in the POC data product ***(Ongoing work)***.

(3) Perform scientific analysis of satellite-derived POC over available timeline of ocean color missions ***(Initial results presented at Ocean Sciences Meeting 2020. This work will continue throughout the project and beyond)***.

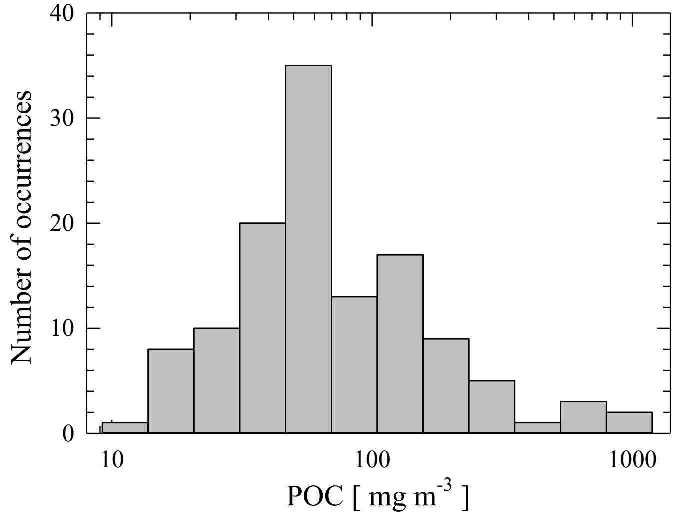
(4) Support the implementation of refined POC algorithms into the standard ocean color processing stream ***(To be initiated upon completion of (1) and (2))***.

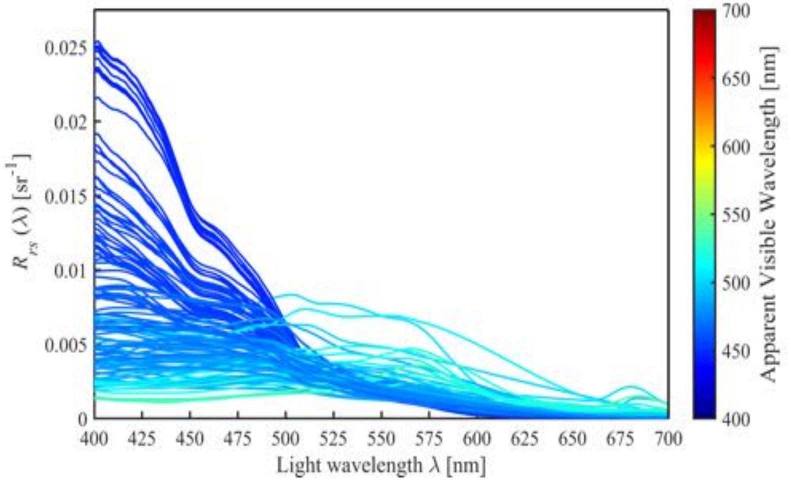
Task completed: Algorithm development dataset

- Globally representative field dataset of POC and $R_{rs}(\lambda)$ was assembled using QA/QC procedures and environmentally-based inclusion/exclusion criteria
- Balanced representation of ocean basins and adequate coverage of broad range of POC and bio-optical properties was achieved



Distribution of POC and $R_{rs}(\lambda)$ spectra in the dataset



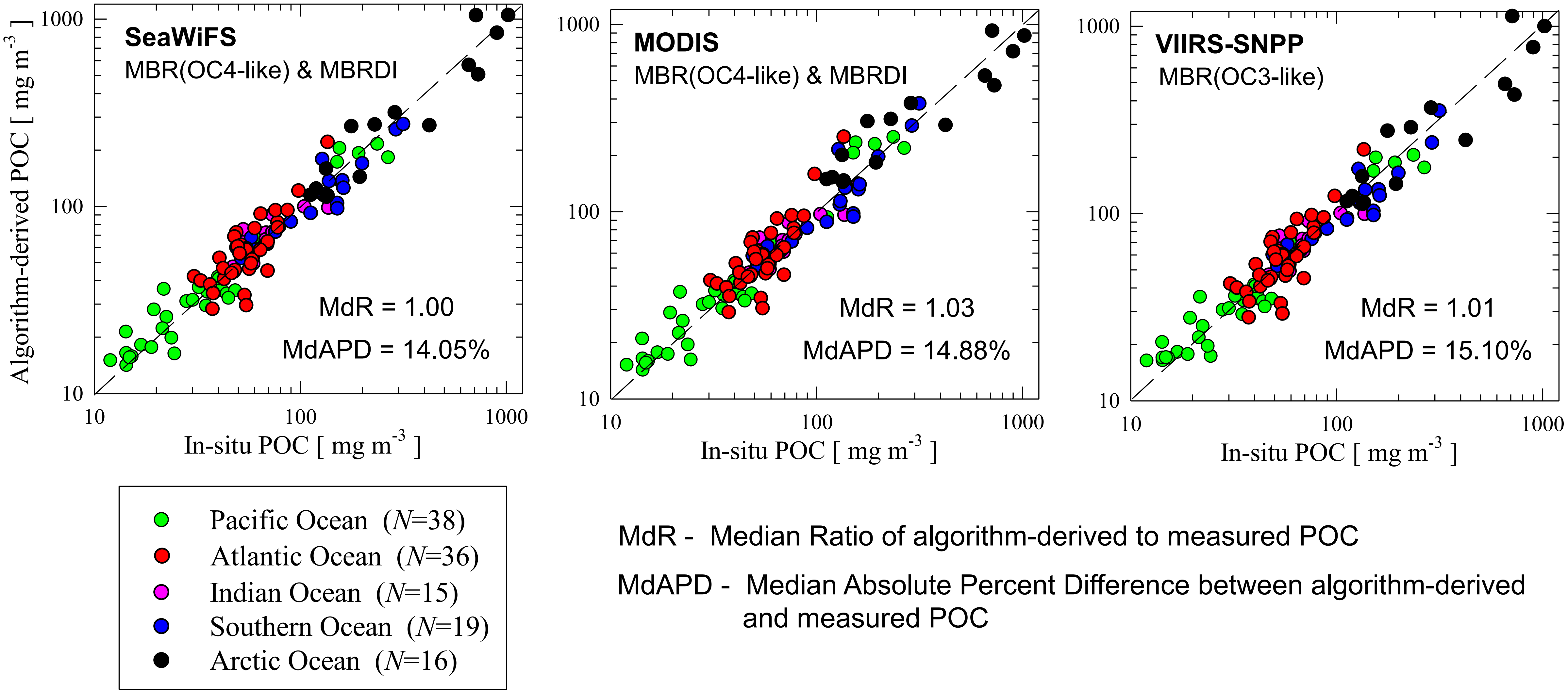


Task completed: Formulation of new POC algorithms

- Seven classes of algorithmic approaches, each including 4 to 13 functions utilizing different spectral bands, combination of bands, and/or degree of polynomials, were examined (in total 55 functions)
- The best performing algorithm was established for each satellite sensor (**typically a combination of MBR(OC4-like) and MBRDI functions except for MBR(OC3-like) alone for VIIRS**) based on comparative analysis of multiple statistical metrics of performance

Algorithmic approach	No. of candidate functions
Band Ratio (BR) with a power function including Maximum Band Ratio (MBR) *(the BR approach is used in the current standard POC algorithm)*	4
Maximum Band Ratio (MBR) with polynomials *(OCx-like algorithms where x is the number of bands)*	7
Color Index (CI) - three-band difference *(also includes a combination of CI with MBR OC4-like algorithm)*	4
Multiple Linear Regression (MLR) with two or three bands	6
Normalized Difference Carbon Index (NDCI) with polynomials including Maximum Normalized Difference Carbon Index (MNDCI)	12
Modified Maximum Normalized Difference Carbon Index (MMNDCI) with polynomials	9
Band Ratio Difference Index (BRDI) with polynomials including **Maximum Band Ratio Difference Index (MBRDI)**	13
Total	**55**

Algorithm-derived vs. measured POC for the development dataset

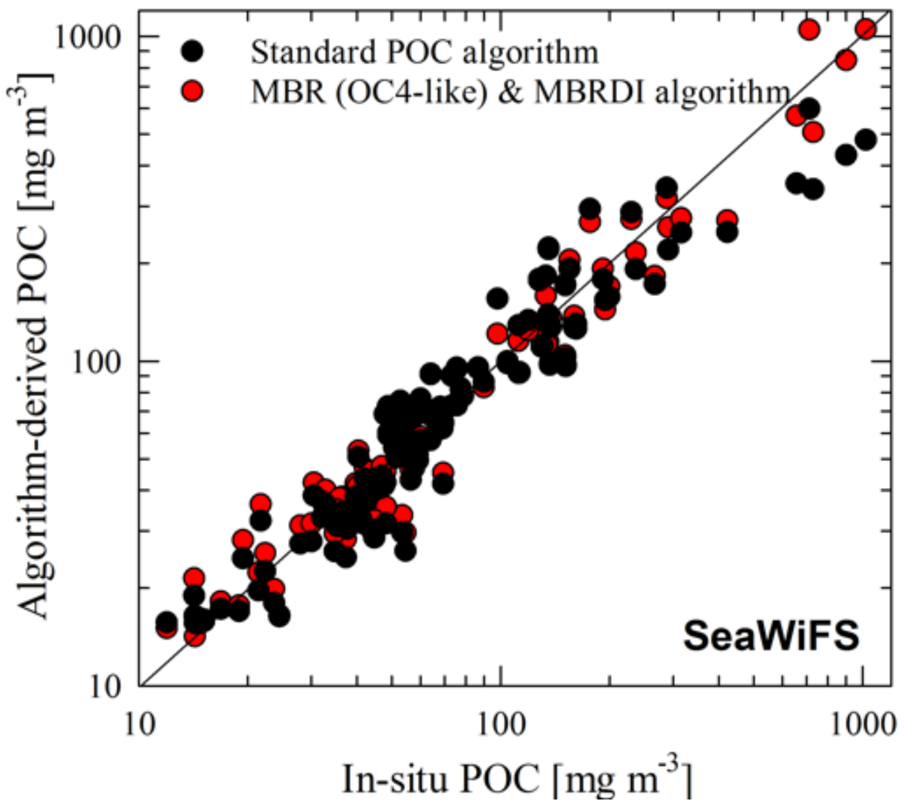


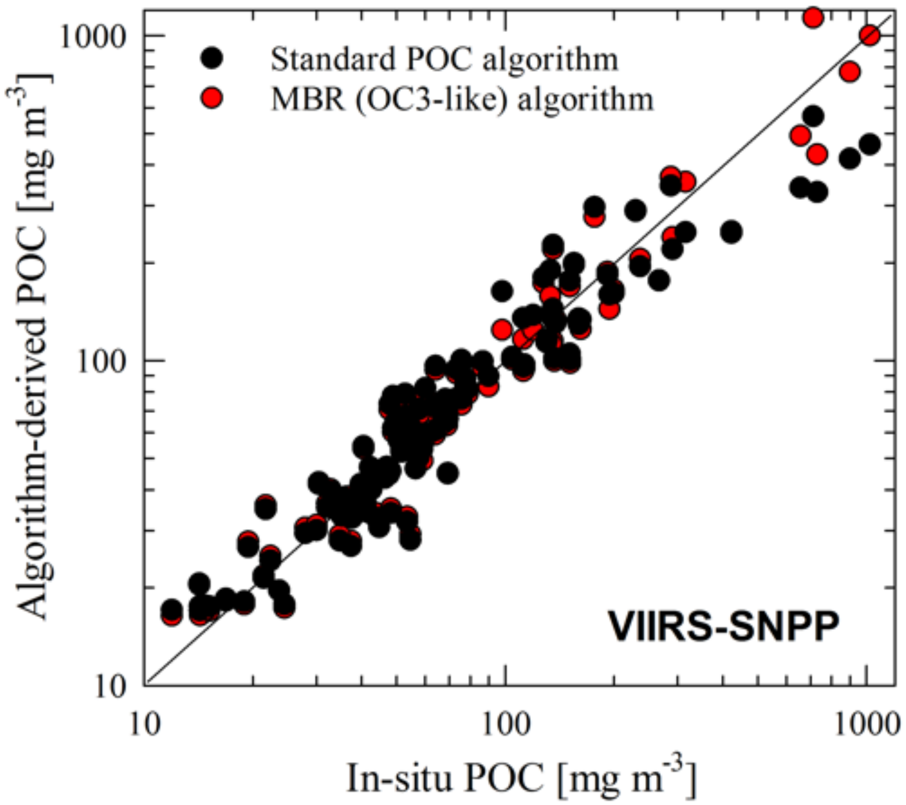
MdR - Median Ratio of algorithm-derived to measured POC

MdAPD - Median Absolute Percent Difference between algorithm-derived and measured POC

Ongoing work on algorithm performance: Validation with independent in-situ datasets and satellite matchups

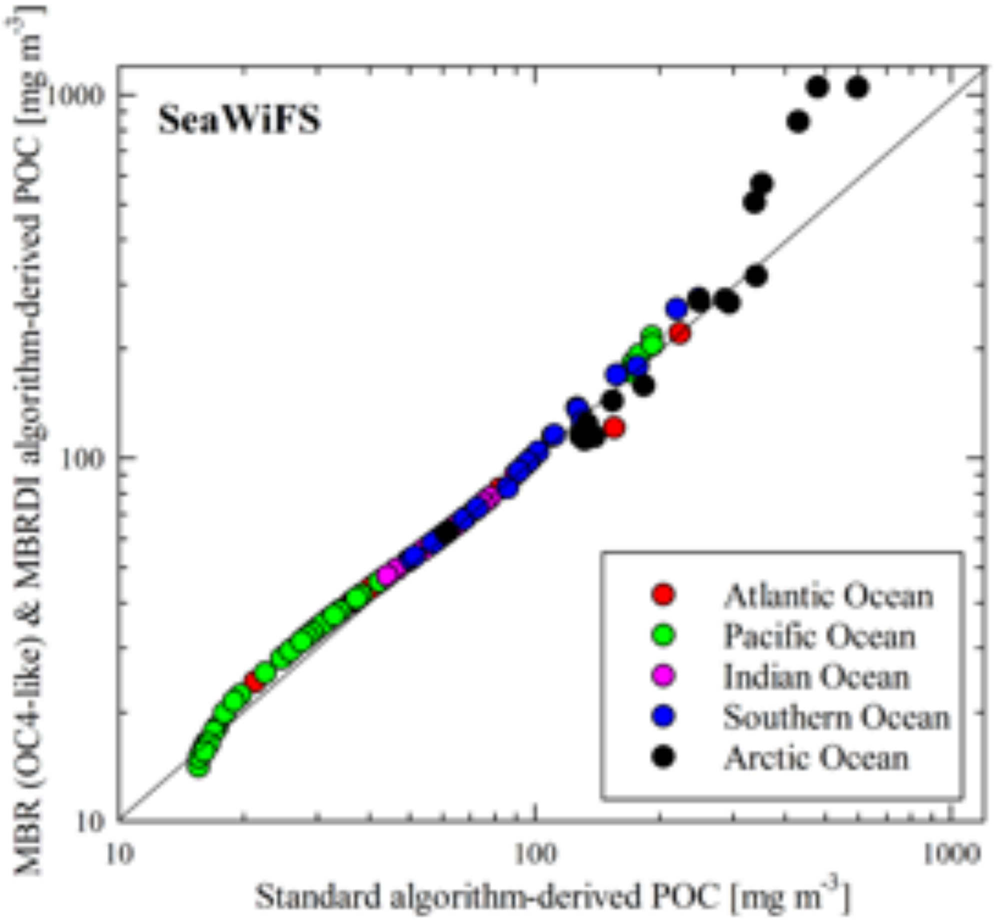
Comparison of standard and new POC algorithms for SeaWiFS and VIIRS for the development dataset

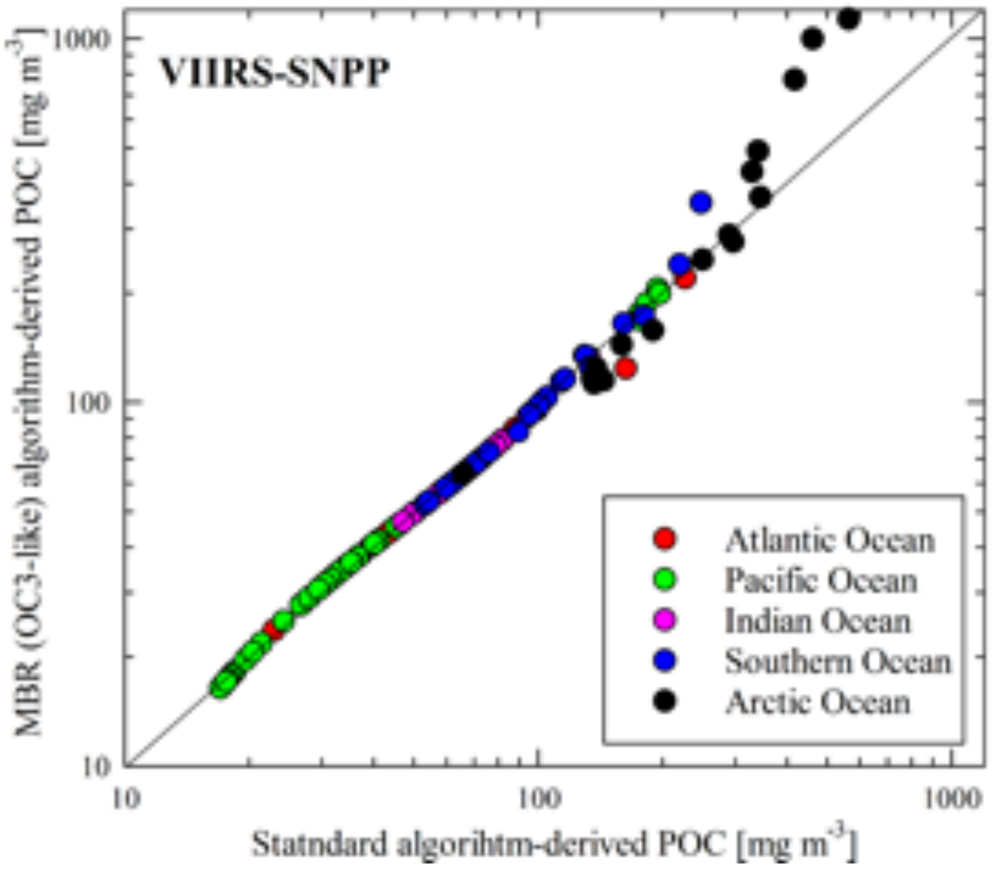




SeaWiFS: Standard algorithm	SeaWiFS: New algorithm	VIIRS-SNPP: Standard algorithm	VIIRS-SNPP: New algorithm
MdR = 0.95	MdR = 1.00	MdR = 1.01	MdR = 1.01
MdAPD = 18.11%	MdAPD = 14.05%	MdAPD = 17.32%	MdAPD = 15.10%

POC derived from new algorithm vs. POC derived from standard algorithm for the development dataset





Final ensemble MBR(OC4-like) & MBRDI algorithm for SeaWiFS

MBRDI-Quintic→ $\text{MBRDI} = max\left(\frac{[R_{rs}(443) - R_{rs}(555)]}{R_{rs}(490)}, \frac{[R_{rs}(490) - R_{rs}(555)]}{R_{rs}(510)}\right)$

$POC_{MBRDI} = 10^{(2.4956 - 0.8778\times(MBRDI) - 0.1156\times(MBRDI)^2 + 0.2866\times(MBRDI)^3 - 0.0312\times(MBRDI)^4 - 0.0325\times(MBRDI)^5)}$

Initial weights $w_{MBRDI} = \left\{\begin{matrix} 0 \; if \, POC_{MBRDI} > 30 \; mg \; m^{-3} \\ 1 \; if \, POC_{MBRDI} < 15 \; mg \; m^{-3} \\ 0 \le w_{MBRDI} \le 1 \; if \;\; 15 \le POC_{MBRDI} \le 30 \; mg \; m^{-3} \\ where \; w_{\text{MBRDI}} = 1 - \log 10 \, [(0.6 \times POC_{MBRDI}) - 8] \end{matrix}\right\}$

MBR-Cubic → $MBR = \max\left(\frac{R_{rs}(443)}{R_{rs}(555)}, \frac{R_{rs}(490)}{R_{rs}(555)}, \frac{R_{rs}(510)}{R_{rs}(555)}\right)$

$POC_{MBR} = 10^{(2.4960 - 2.1630\times log10(MBR) + 2.0850\times(log10(MBR))^2 - 1.1060\times(log10(MBR)^3)}$

Initial weights $w_{MBR} = \left\{\begin{matrix} 1 \; if \, POC_{MBR} > 30 \; mg \; m^{-3} \\ 0 \; if \, POC_{MBR} < 15 \; mg \; m^{-3} \\ 0 \le w_{MBR} \le 1 \; if \;\; 15 \le POC_{MBR} \le 30 \; mg \; m^{-3} \\ \text{where } w_{\text{MBR}} = \log 10 \, [(0.6 \times POC_{MBR}) - 8] \end{matrix}\right\}$

Ensemble POC algorithm

$$W_{MBRDI} = \left(\frac{w_{MBRDI} + (1 - w_{MBR})}{2}\right)$$

$$W_{MBR} = 1 - W_{MBRDI}$$

where W represents final weights and w represents initial weights

$$POC_{ensemble} = \frac{POC_{MBRDI} \times W_{MBRDI} + POC_{MBR} \times W_{MBR}}{W_{MBRDI} + W_{MBR}}$$