Updates on ocean color algorithms: from Chl a to POC and PIC

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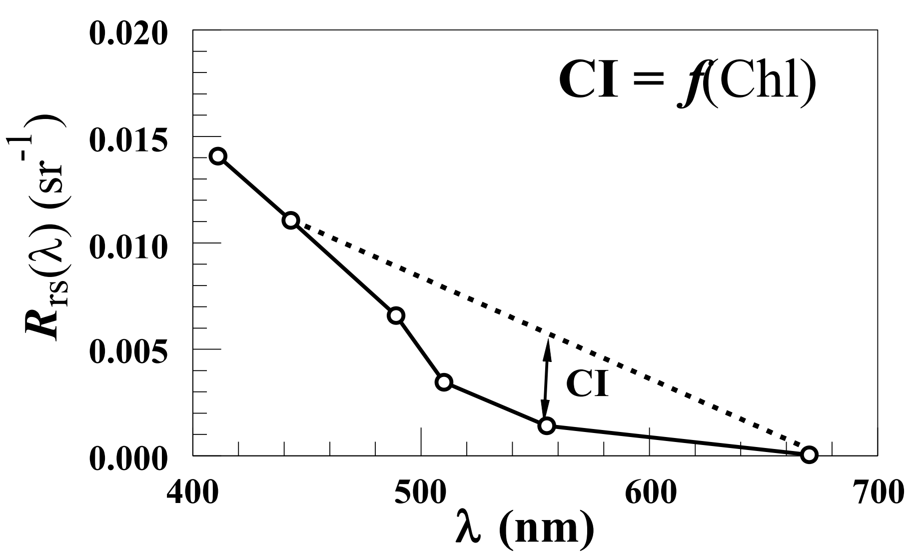
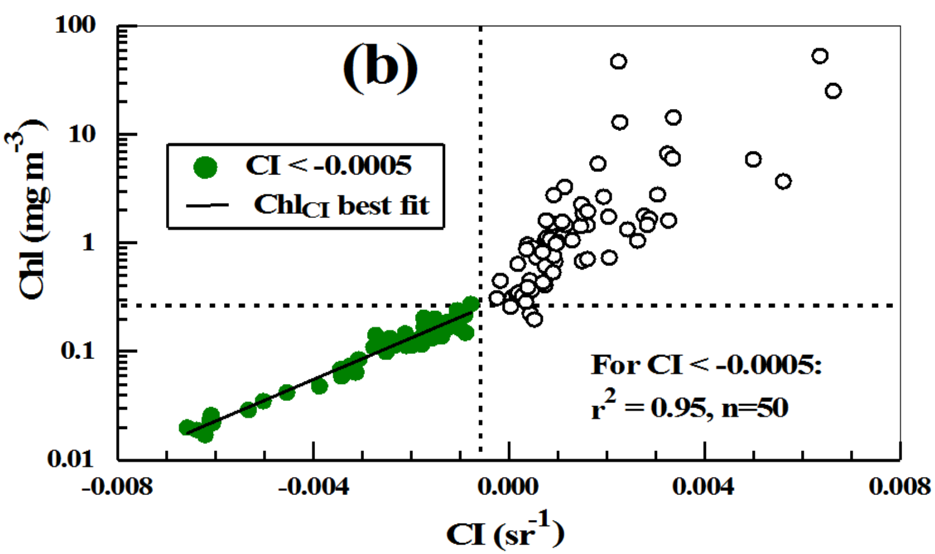
Updates on OCI Chl algorithm

Original proof-of-concept proposed in Hu et al. (2012, JGR)

- CI = *f*(Chl) for Chl < 0.4 mg m^{-3} because it is an index for total absorption
- CI is immune to spectrally flat and additive input R_{rs} errors
- OCI switches from CI to OCx at higher Chl (> 0.3)
- Transition zone of 0.25 – 0.3 for weighted mixing
- Significantly reduced uncertainties and improved image quality and cross-sensor consistency for low-Chl waters
- OCI became default SeaDAS algorithm starting R2014.0

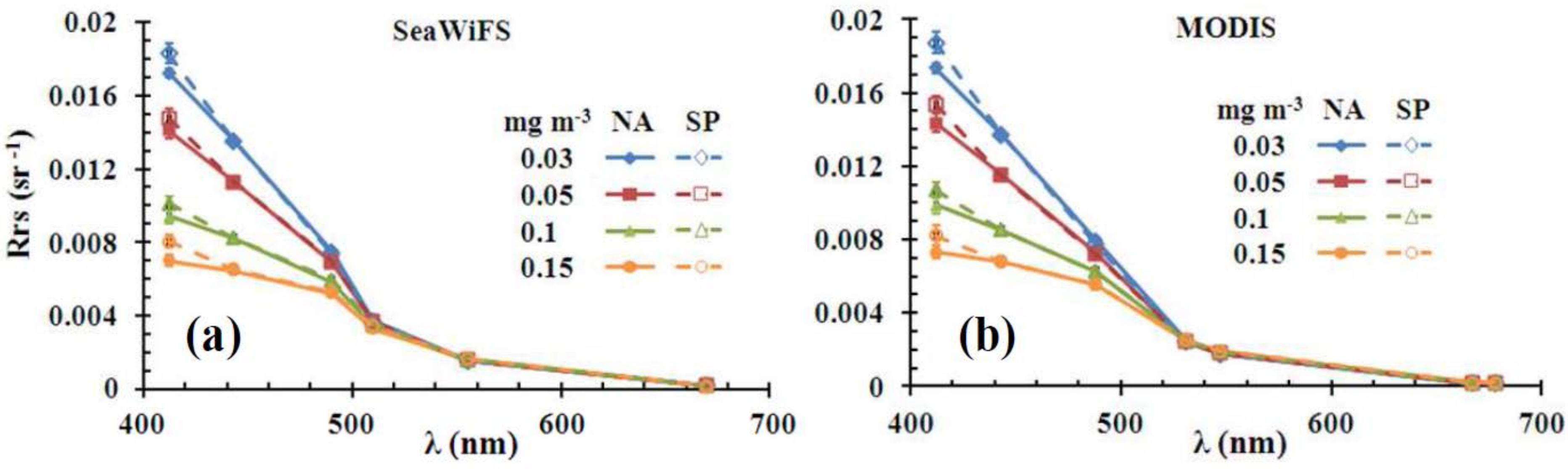




Updates on OCI Chl algorithm

What's the problem?

- Transition zone of 0.25 – 0.3 led to non-smooth transition in global histogram
- Only 50 HPLC-Chl data points were used to tune the CI algorithm coefficients
- Its tolerance to straylight not taken into account in data binning
- CDOM impacts not accounted for

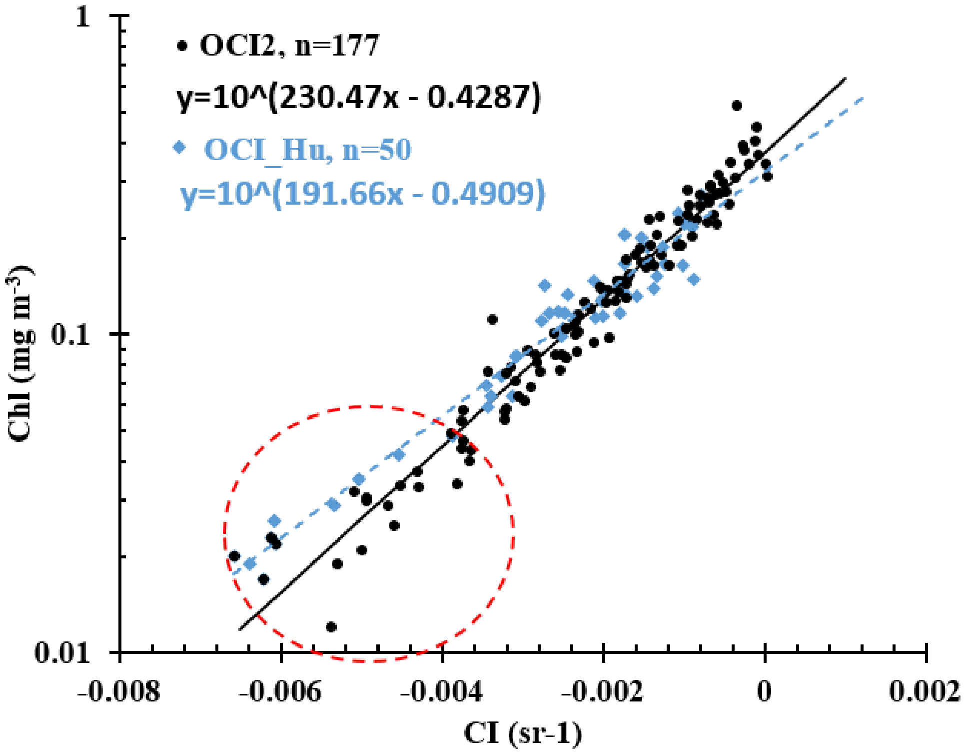


Updates on OCI Chl algorithm

Approaches and Results

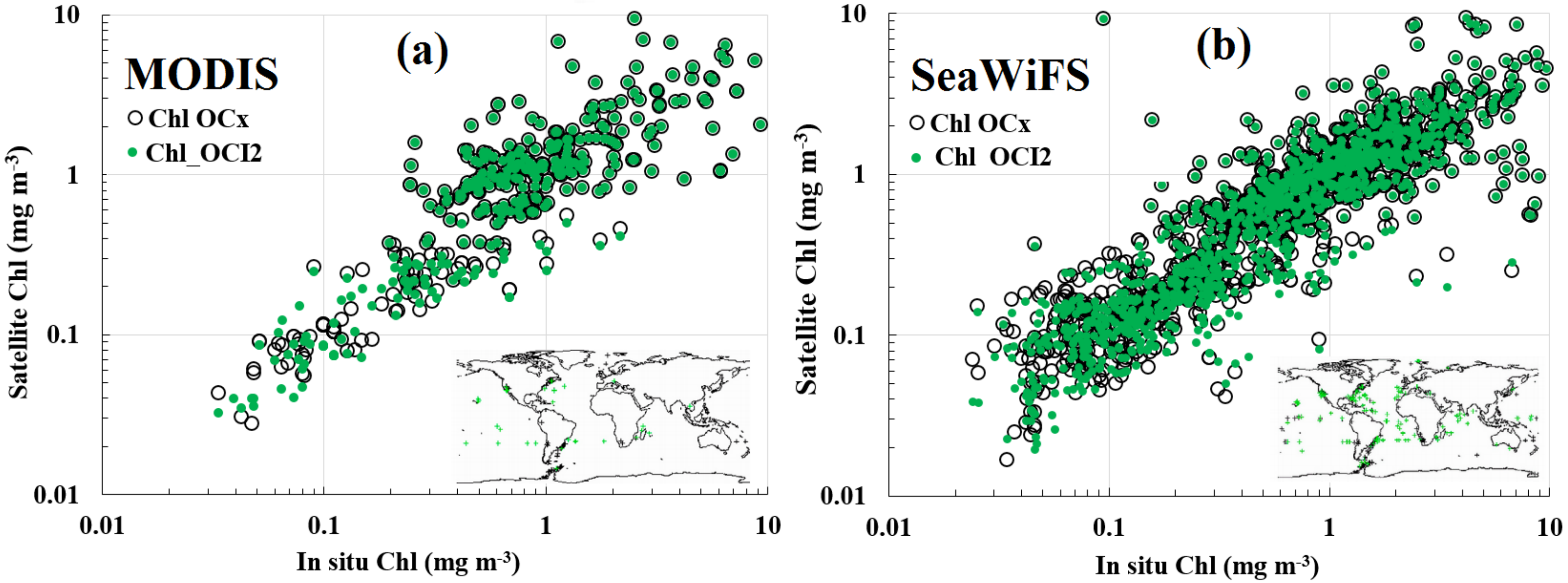
- Include both HPLC and fluorometric Chl in algorithm tuning
- Enlarge the transition zone to 0.25 – 0.4 mg m^{-3}
- Evaluate straylight flagged pixels on data quality
- Empirical correction using 412-nm and other bands

- Chl < 0.4 mg m^{-3} from NOMAD data (1051 points)
- Gridded into log space for Chl (177 points)



Updates on OCI Chl algorithm

Approaches and Results – SeaBASS validation

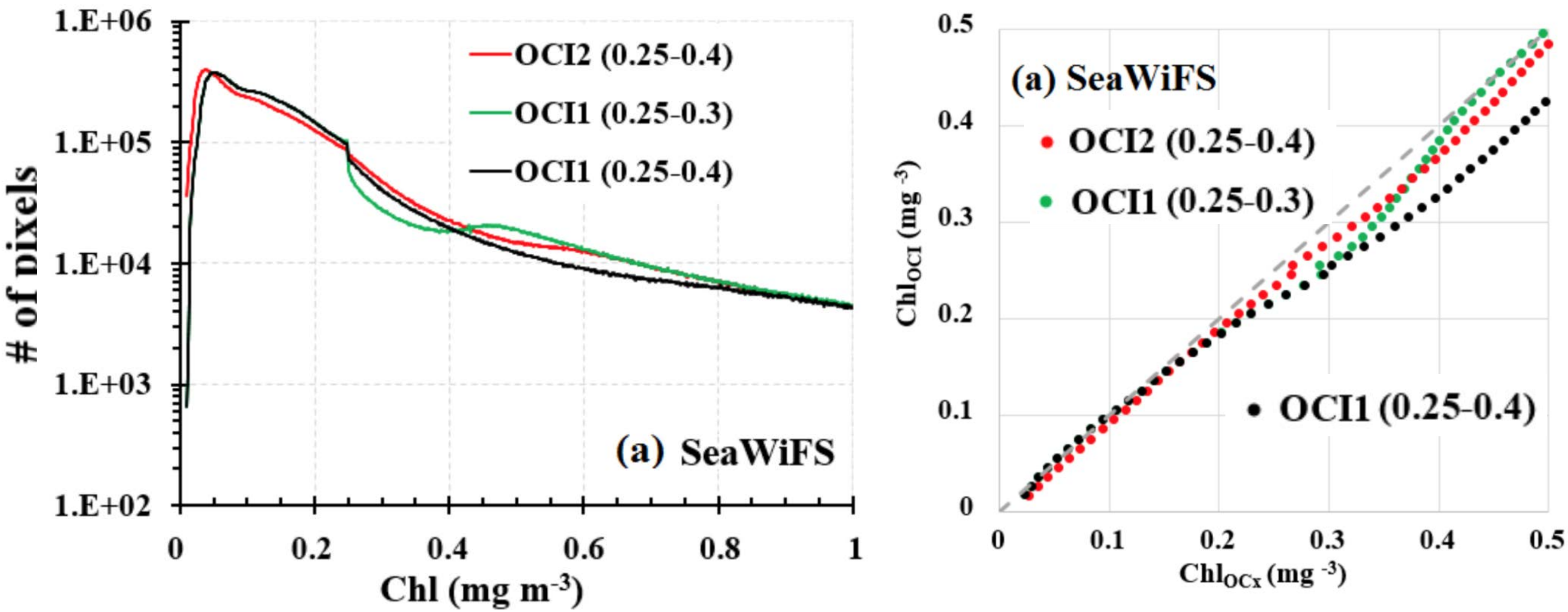


		RMSE	URMSE	Mean Ratio	Median ratio	MRE	R^2	$\log(R^2)$	N
MODISA	OCx	77.7%	44.2%	1.24	1.05	32.0%	0.42	0.66	63
	CI1	43.9%	32.7%	1.15	1.04	25.4%	0.62	0.71	63
	CI2	51.2%	37.6%	1.12	0.94	35.2%	0.59	0.71	63
SeaWiFS	OCx	535.8%	54.2%	1.79	1.19	41.5%	0.01	0.33	357
	CI1	91.8%	47.2%	1.40	1.16	36.8%	0.31	0.39	357
	CI2	102.0%	49.6%	1.38	1.14	39.4%	0.28	0.39	357

Updates on OCI Chl algorithm

Approaches and Results – Smoother Transition

- Smoother transition than original OCI (0.25 – 0.3) or adjusted OCI (0.25 – 0.4)
- Same for all sensors (SeaWiFS, MODISA, VIIRS)



Statistics generated from 1-year global daily data

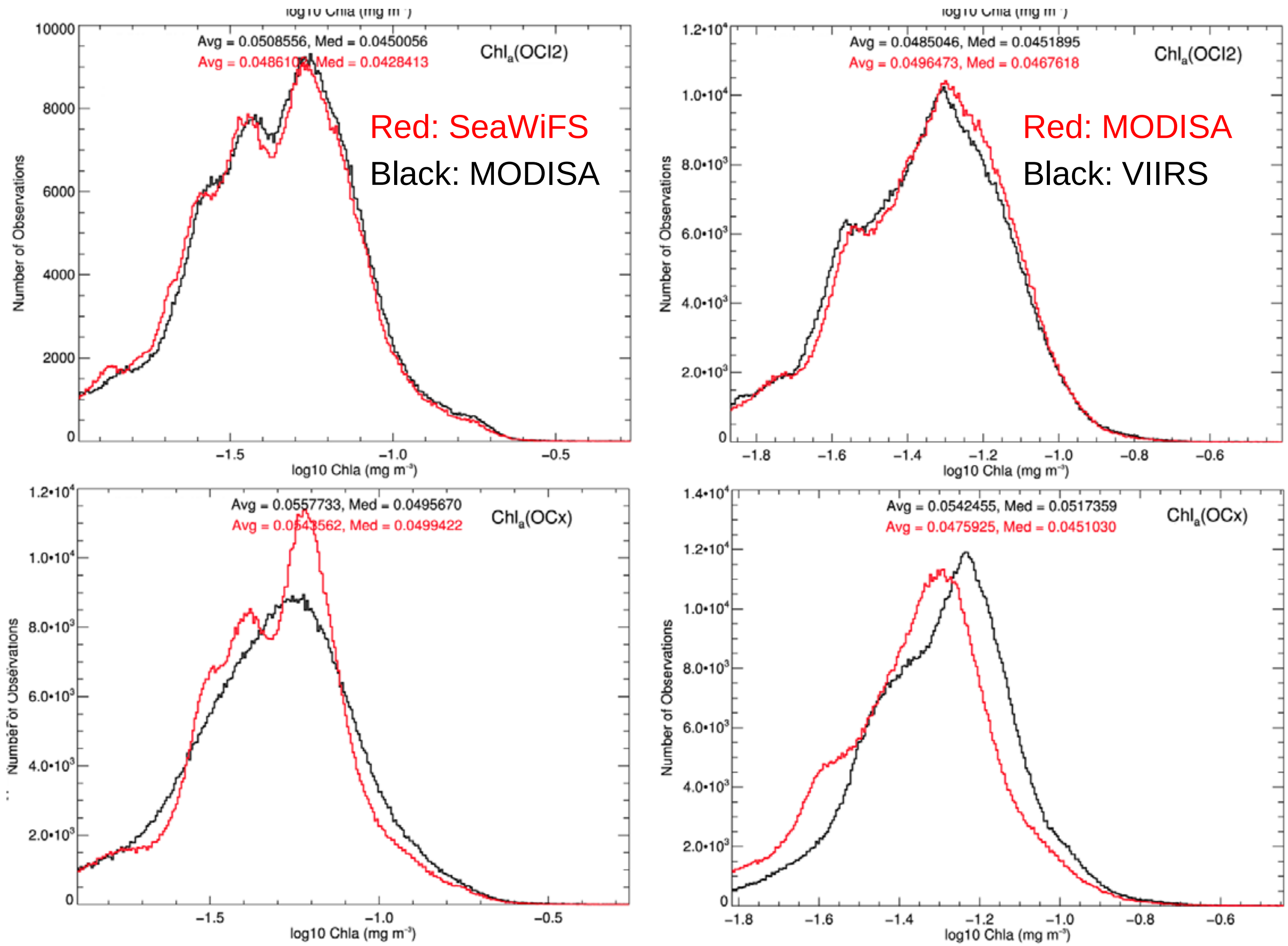
Updates on OCI Chl algorithm

Approaches and Results – Cross-sensor Consistency

Global oligotrophic water for November 2010 (left) and November 2013 (right)

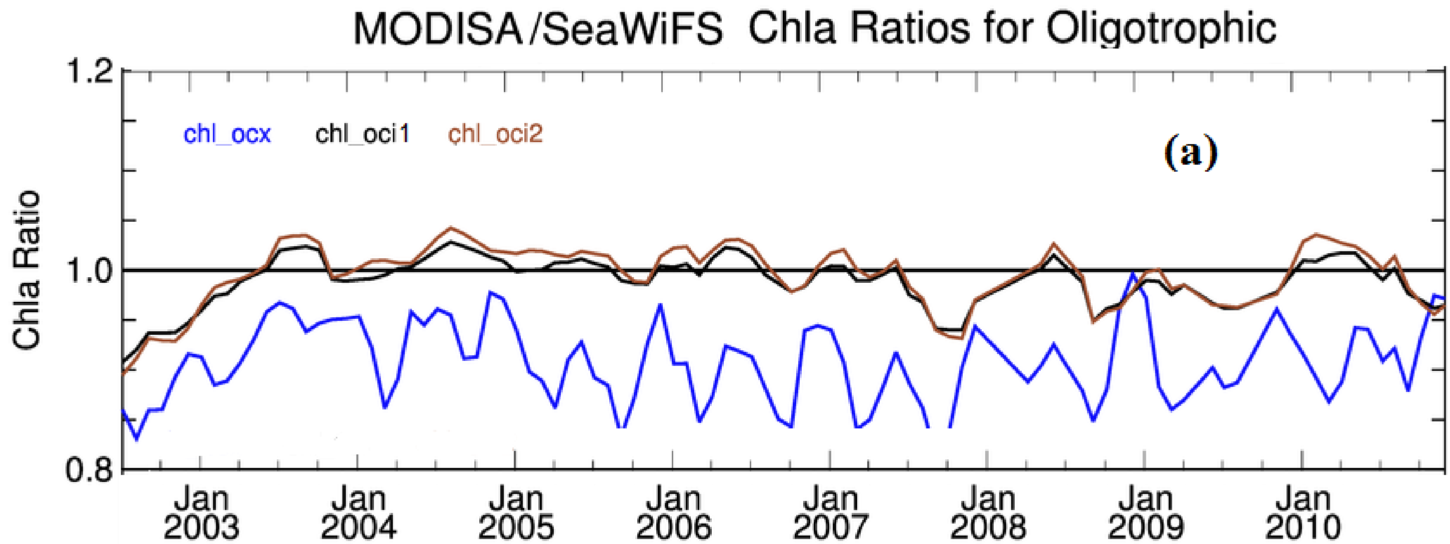
OCI2

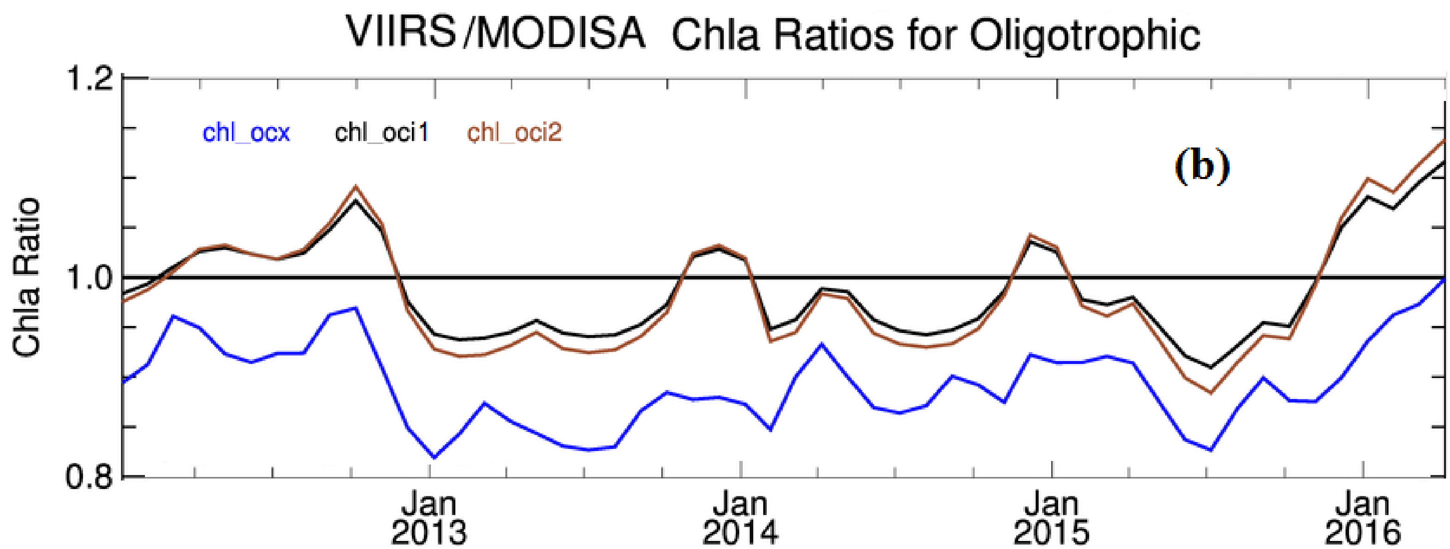
OCx



Updates on OCI Chl algorithm

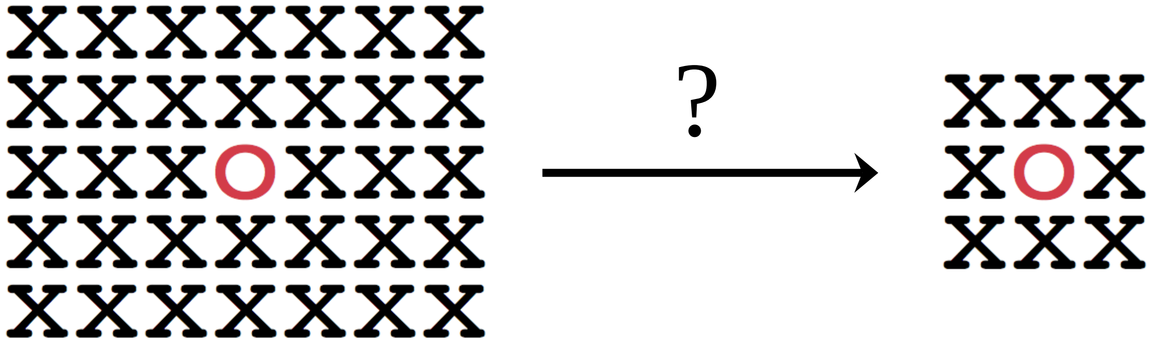
Approaches and Results – Cross-sensor Consistency

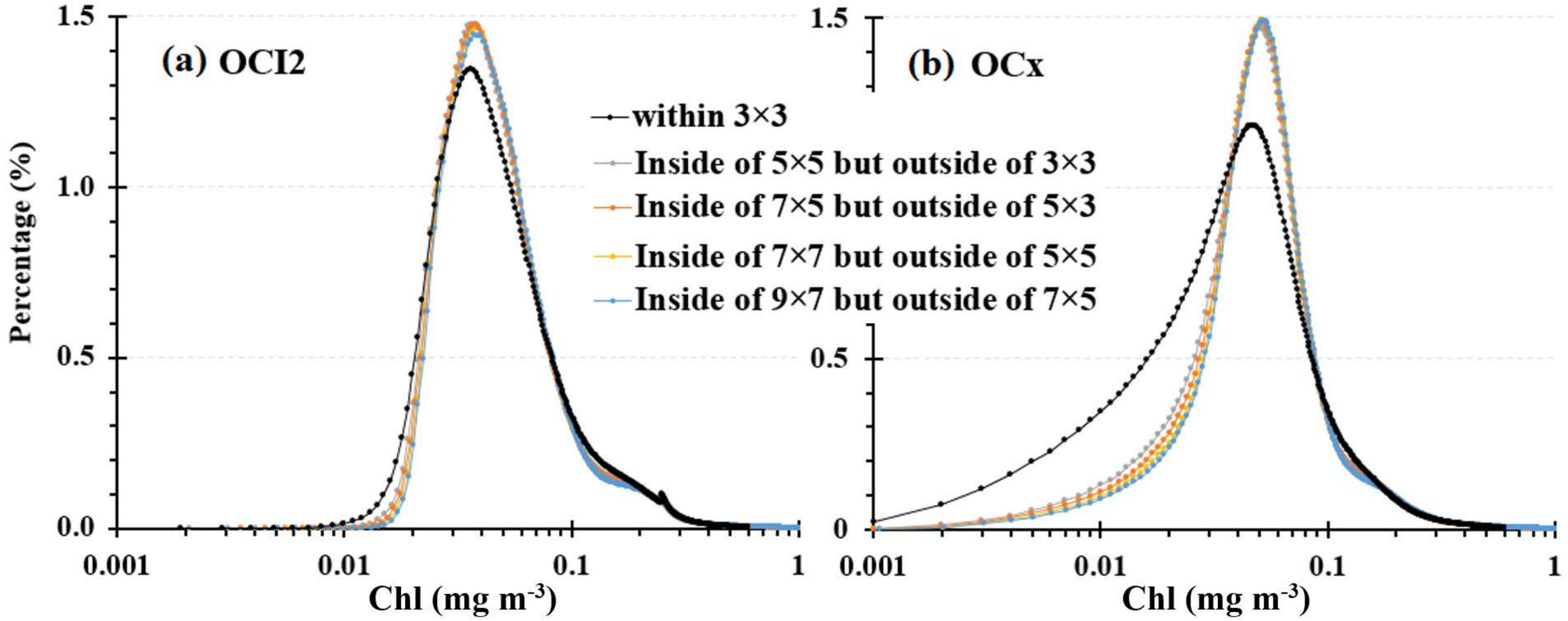




Updates on OCI Chl algorithm

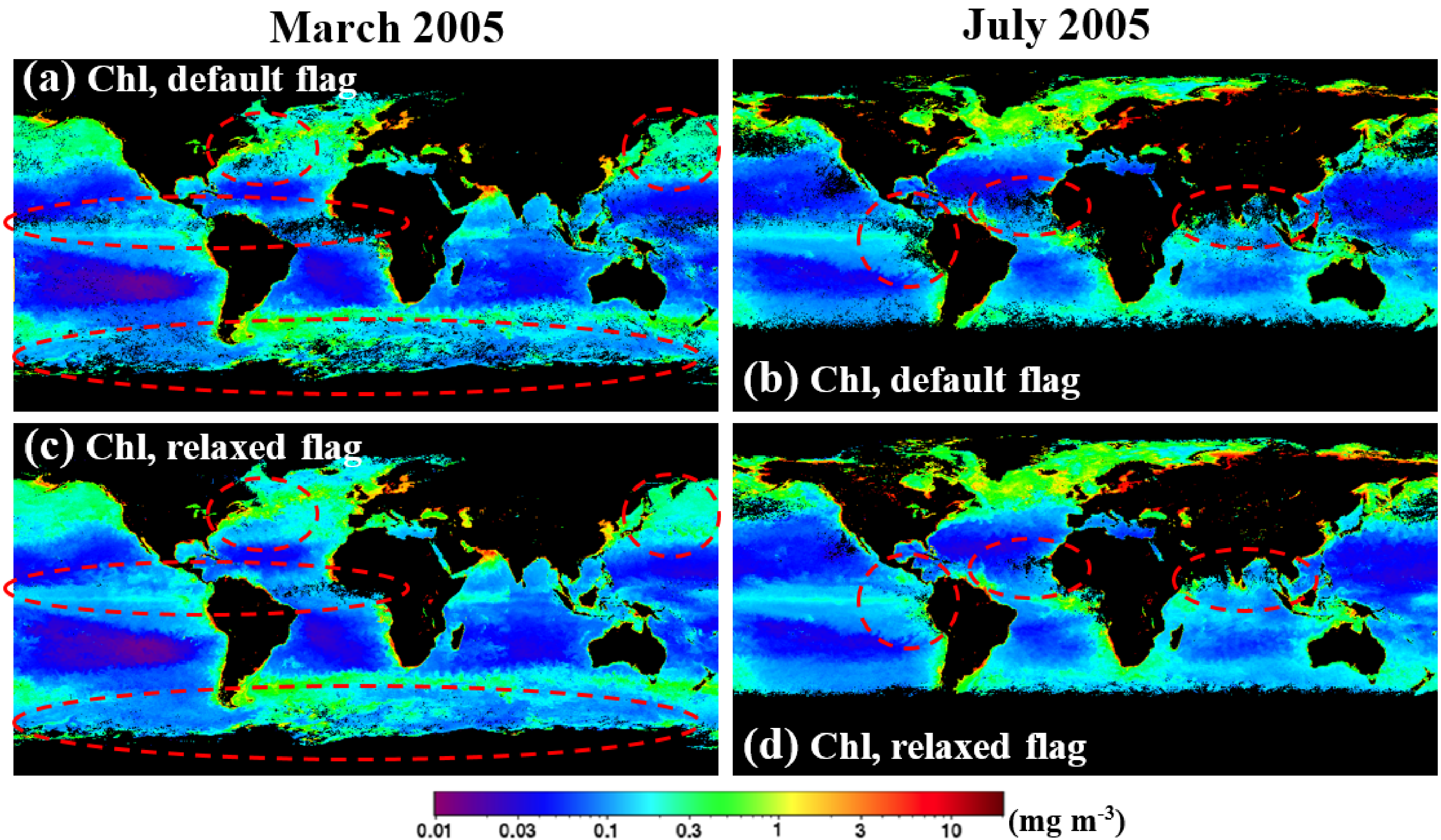
Approaches and Results – Relaxing Straylight Mask





Updates on OCI Chl algorithm

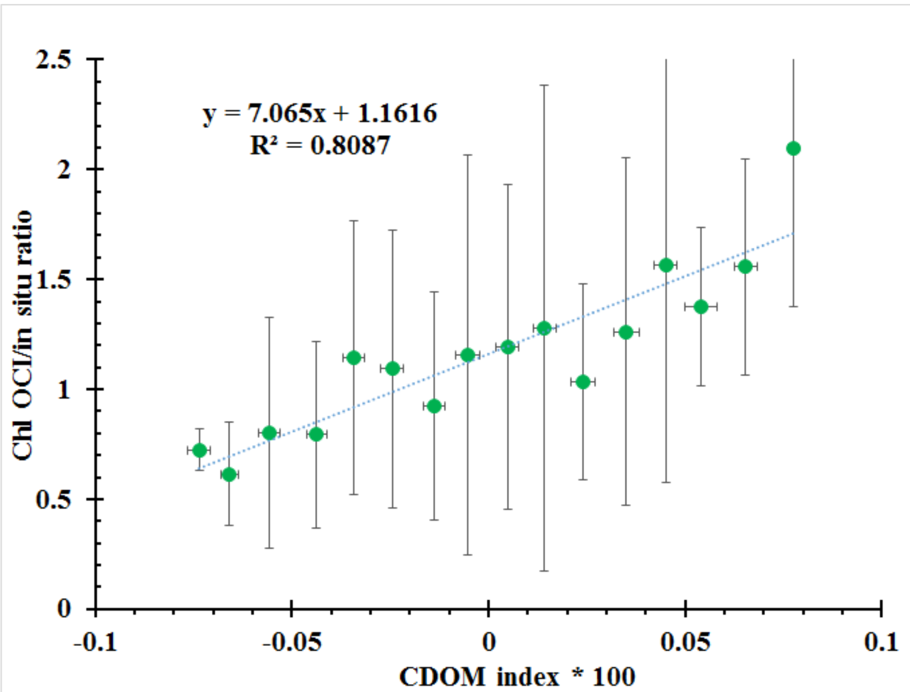
Approaches and Results – Relaxing Straylight Mask



Updates on OCI Chl algorithm

Approaches and Results – Reducing CDOM Impacts?

Global empirical correction from NOMAD



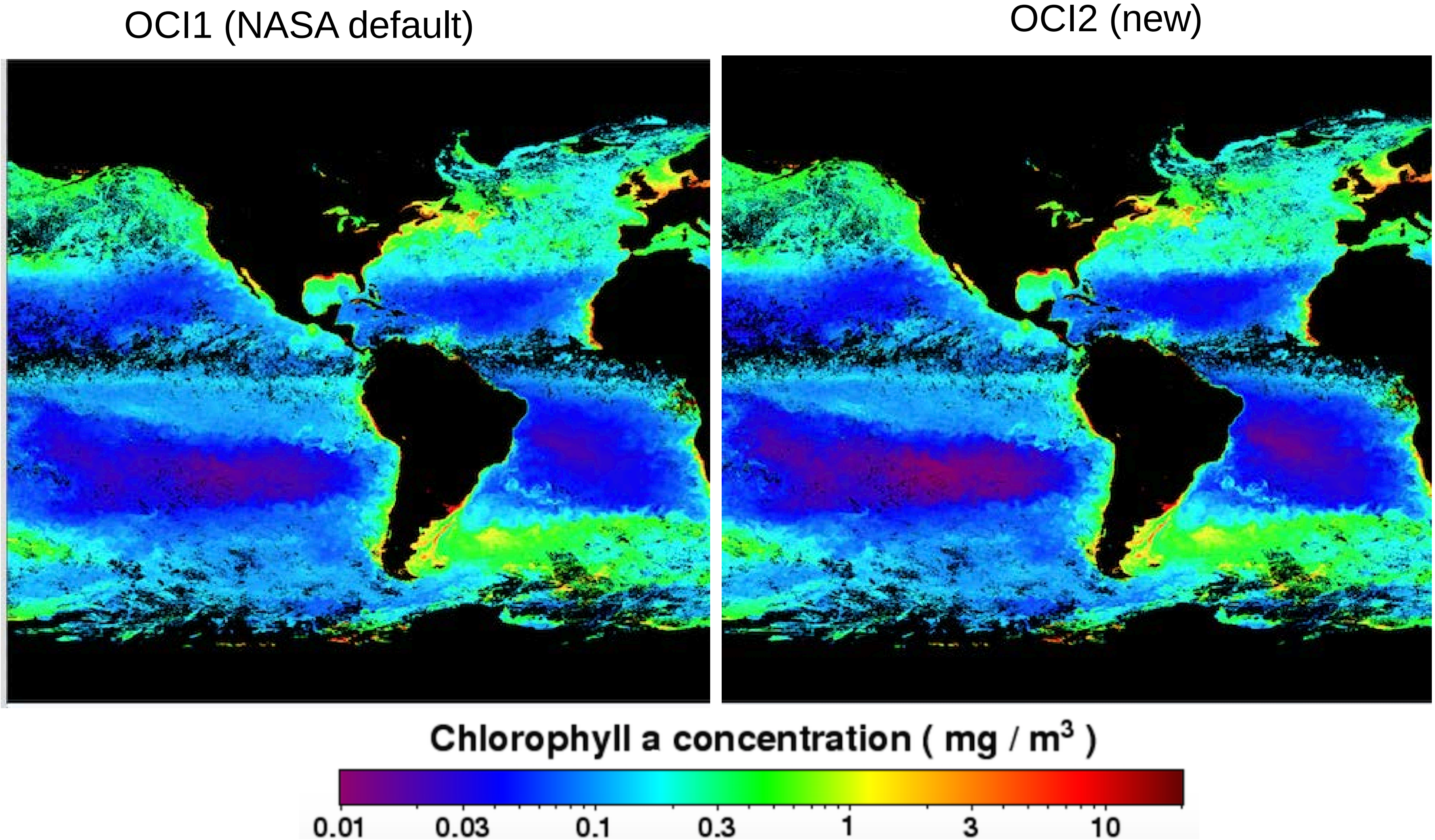
Regional validation from SeaBASS

		Chl satellite/in situ	
Area	**N**	**OCI**	**CDOM corrected**
global	450	1.13 ± 0.76	0.99 ± 0.64
s_pacific	21	0.63 ± 0.22	0.68 ± 0.28
n_pacific	70	1.02 ± 0.9	0.85 ± 0.68
n_atlantic	63	1.15 ± 0.65	0.94 ± 0.54
s_atlantic	48	0.92 ± 0.42	0.86 ± 0.41
Others	248	1.09 ± 0.68	1.25 ± 0.79

Conclusion: doesn't appear to work!

Updates on OCI Chl algorithm

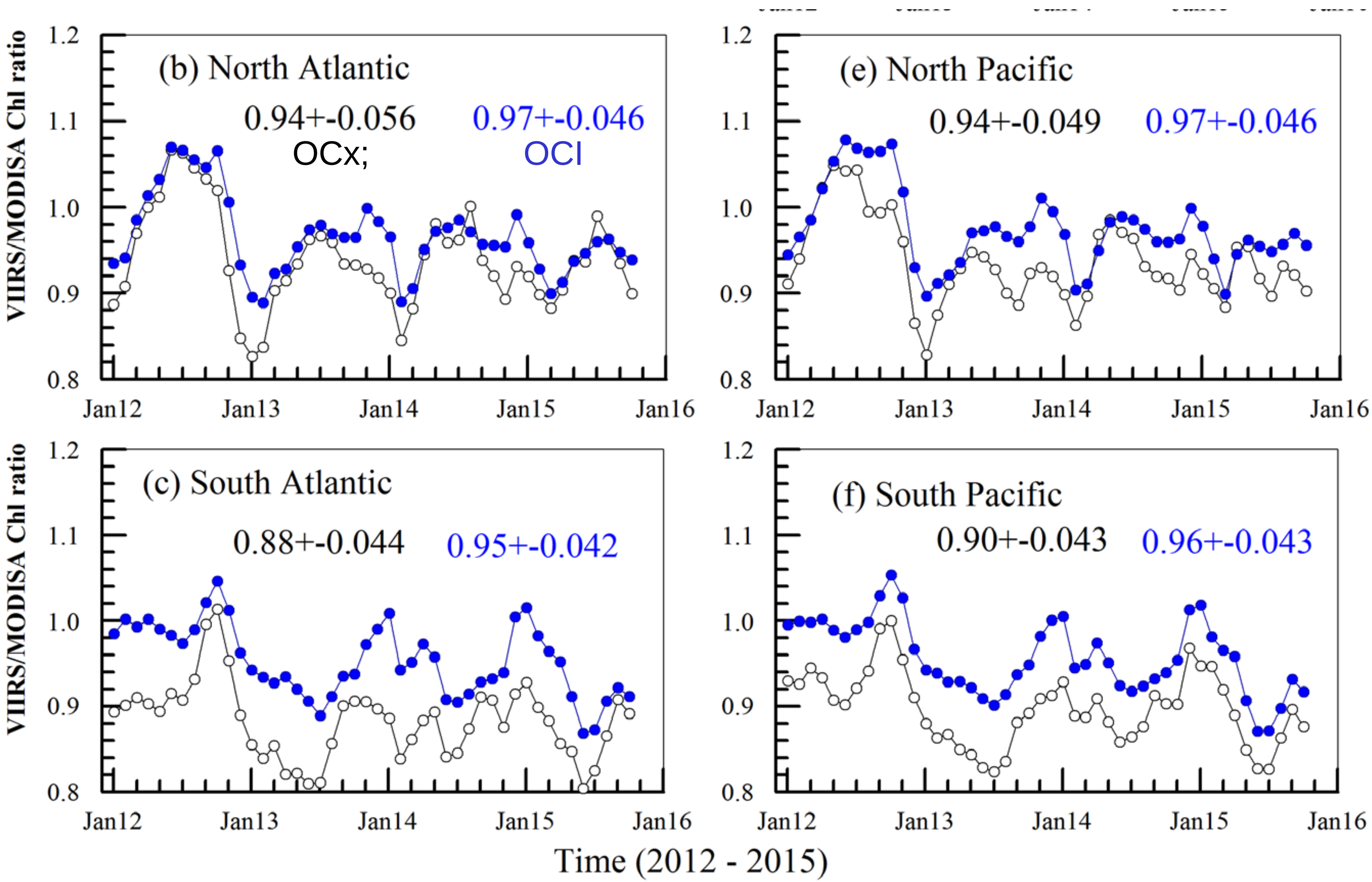
Remaining issues – Which one is closer to truth?



Updates on OCI Chl algorithm

Remaining issues – the puzzle of opposite seasonality

Opposite seasonality between the two hemispheres - why?



Updates on OCI Chl algorithm

Summary

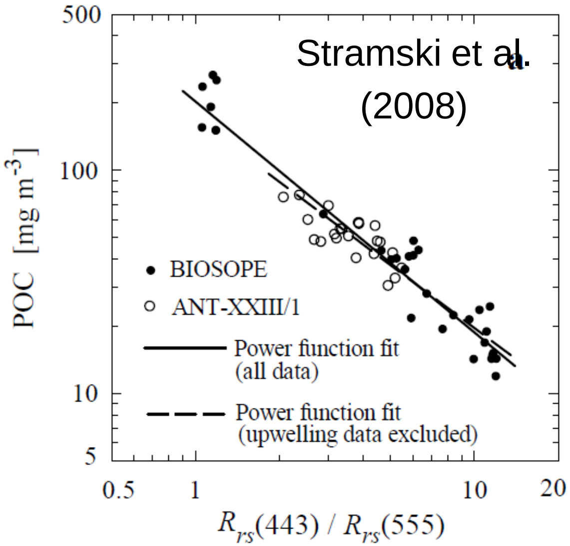
- OCI2 algorithm formulated (new algorithm coefficients, new transition zone)
- Gauged by in situ Chl, OCI2 is comparable to OCI1 in accuracy
- Gauged by algorithm transition, OCI2 is better than OCI1
- Both are better than OCx in product accuracy and cross-sensor consistency
- MODIS 7x5 straylight mask could be relaxed to 3x3, leading to 40% data increase
- Impacts by CDOM still unresolved
- Most importantly, is global minimum Chl in ocean gyres 0.01 or 0.02 mg m^{-3}? Current data cannot resolve this puzzle. Likewise, the opposite seasonality in MODIS/VIIRS Chl ratios between the two hemispheres still remains a puzzle
- In terms of studying climate change, cross-sensor consistency is extremely important but it cannot be evaluated using in situ data alone

- Hu, C., Feng, L., Lee, Z., Franz, B. A., Bailey, S. W., Werdell, P. J., & Proctor, C. W. (2019). Improving satellite global chlorophyll a data products through algorithm refinement and data recovery. Journal of Geophysical Research: Oceans, 124. https://doi.org/10.1029/2019JC014941.

Updates on POC algorithm

From band-ratio to band-difference?

- Several approaches have been proposed. Of these, B/G band ratio algorithm (Stramski et al., 2008) performed better than 2-step IOP-based algorithm for global oceans, which was chosen by NASA as the default to produce global POC. Current B/G algorithm is based on open-cean data with POC < 300 mg m^{-3}.



- Potential “problems”:
  - Applicability to waters with higher POC needs further investigation
  - Same B/G ratio was also used in OCx to estimate Chl, so POC and Chl are not independent
  - All potential algorithm artifacts faced by OCx for clear waters will also be faced by B/G POC

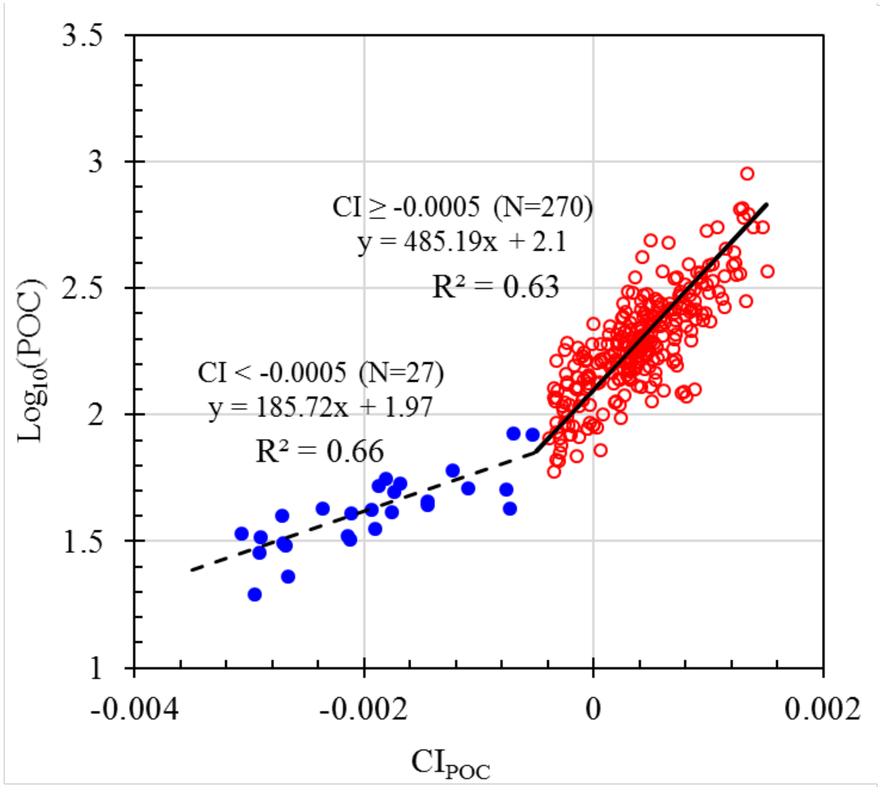
- Solution: formulate a new band-difference approach to overcome these issues?

Updates on POC algorithm

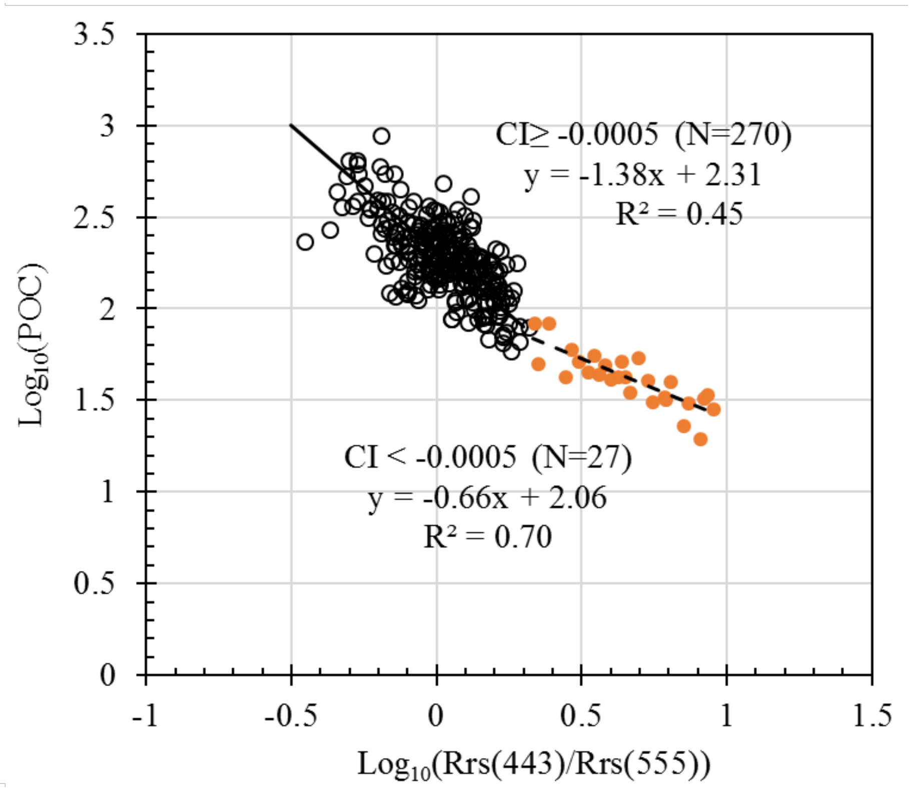
From band-ratio to band-difference?

- CI_{POC} derived from 490, 555, and 670

Satellite CI_{POC} versus in situ POC

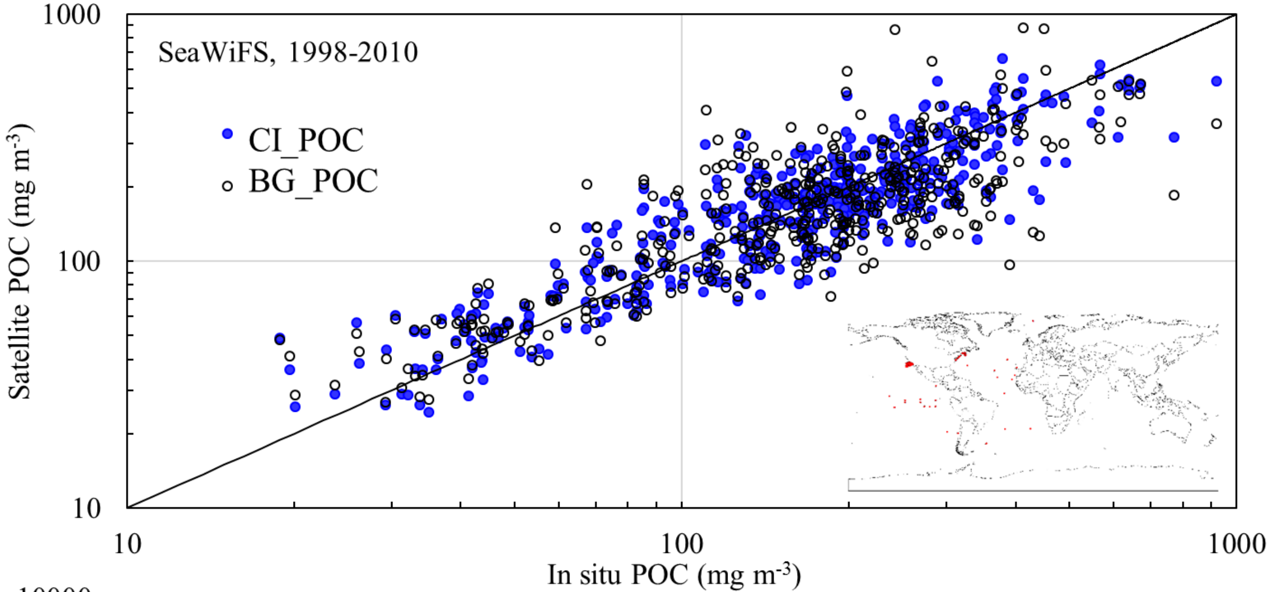


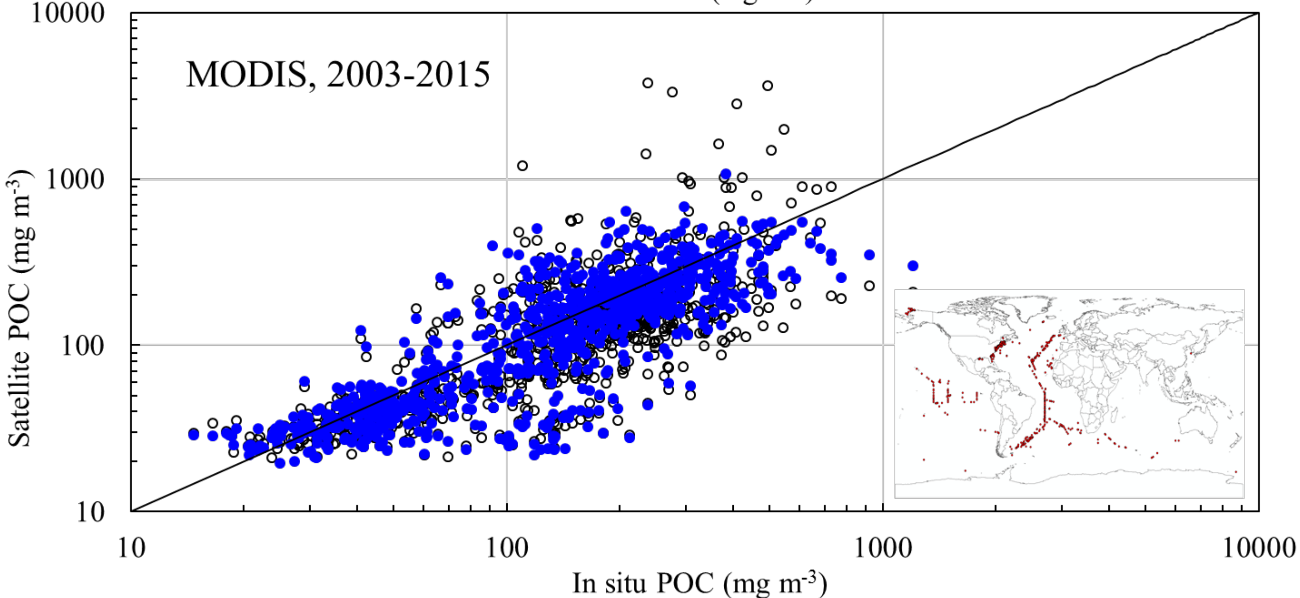
Satellite B/G ratio versus in situ POC



Updates on POC algorithm

Global Evaluation

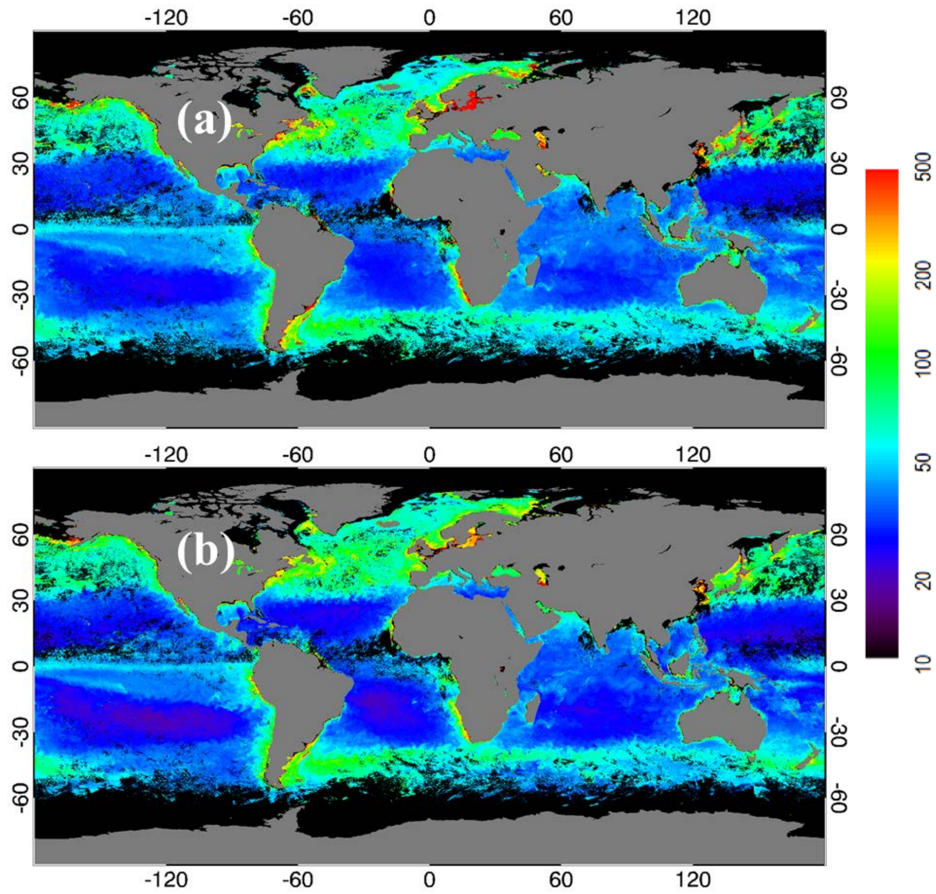




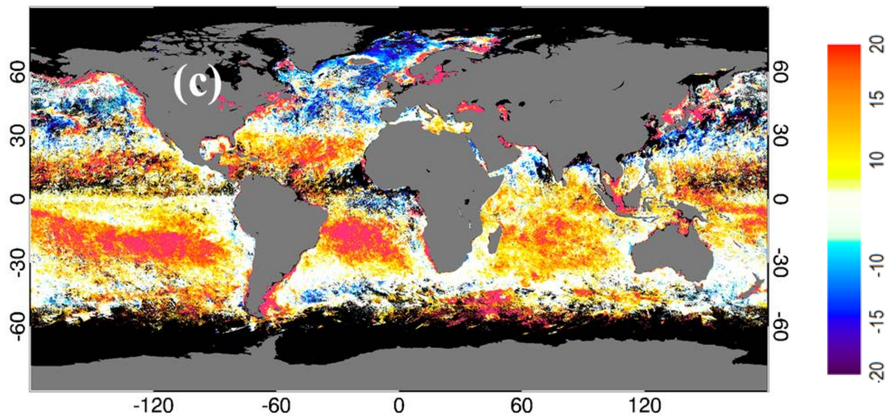
Updates on POC algorithm

Global Evaluation

MODIS March 2010; top: B/G POC
Bottom: CI_{POC} POC



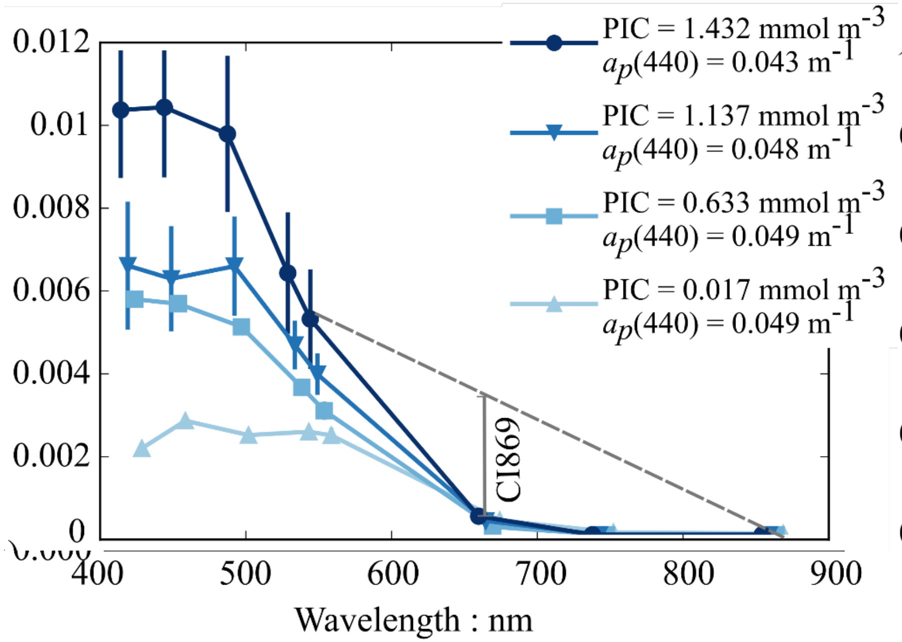
Relative difference (%):
B/G versus CI_{POC}

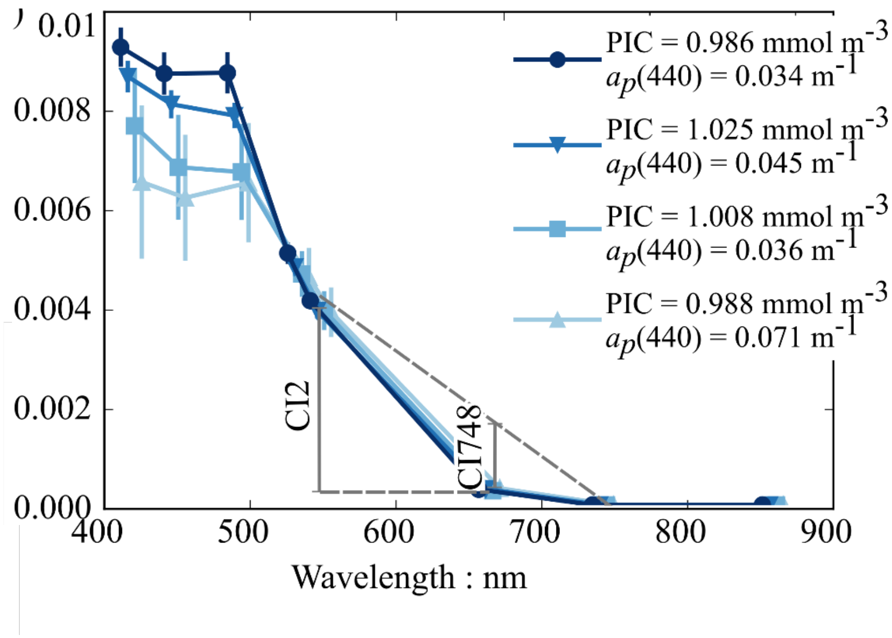


Updates on PIC algorithm

From LUTs or band-difference?

- Current NASA approach uses a merge of Gordon (2001, Red and NIR) for high PIC and Balch (2005, radiative transfer based LUTs) for lower PIC
- Can we extend the band-difference concept to PIC algorithm?
- CI670 sensitive PIC, but not to a_p



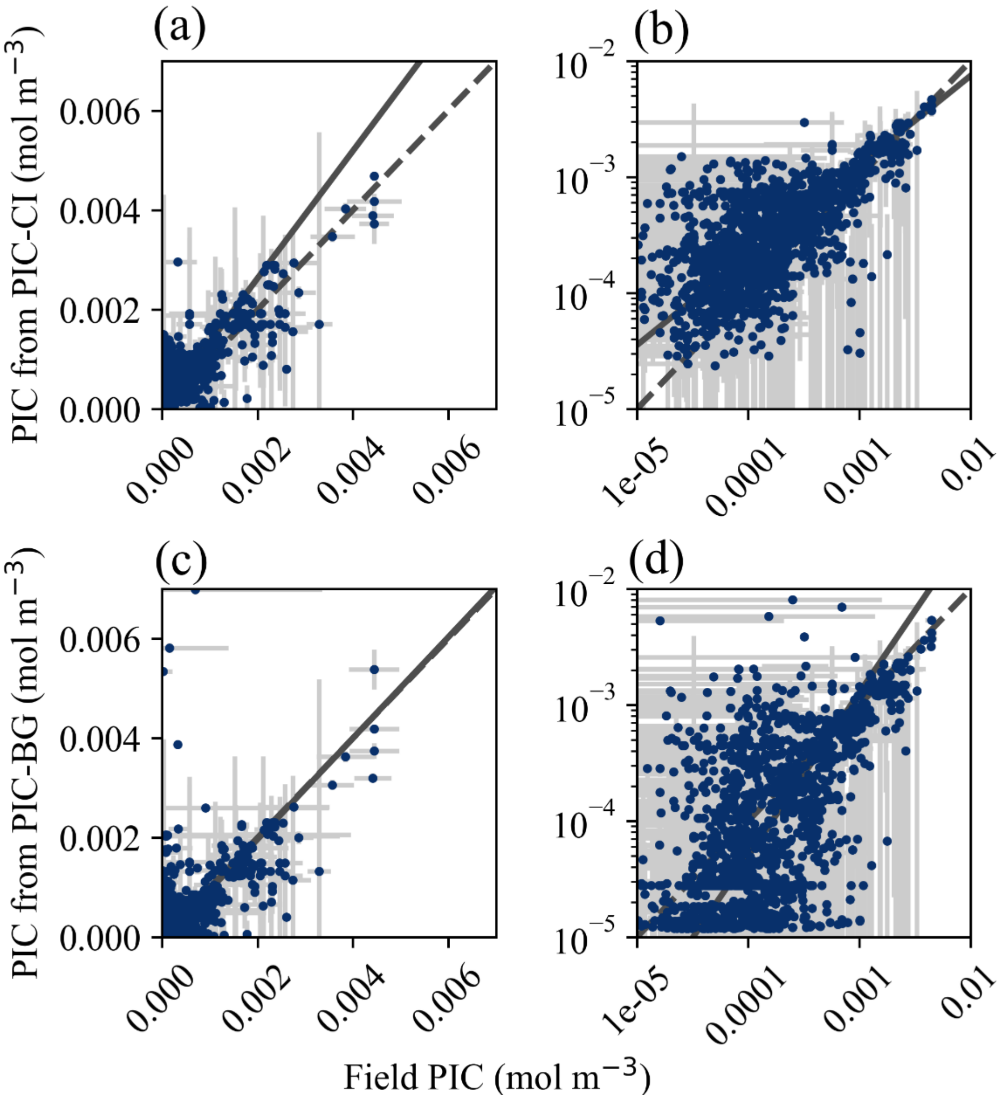


Updates on PIC algorithm

Algorithm Performance

Left: linear scale

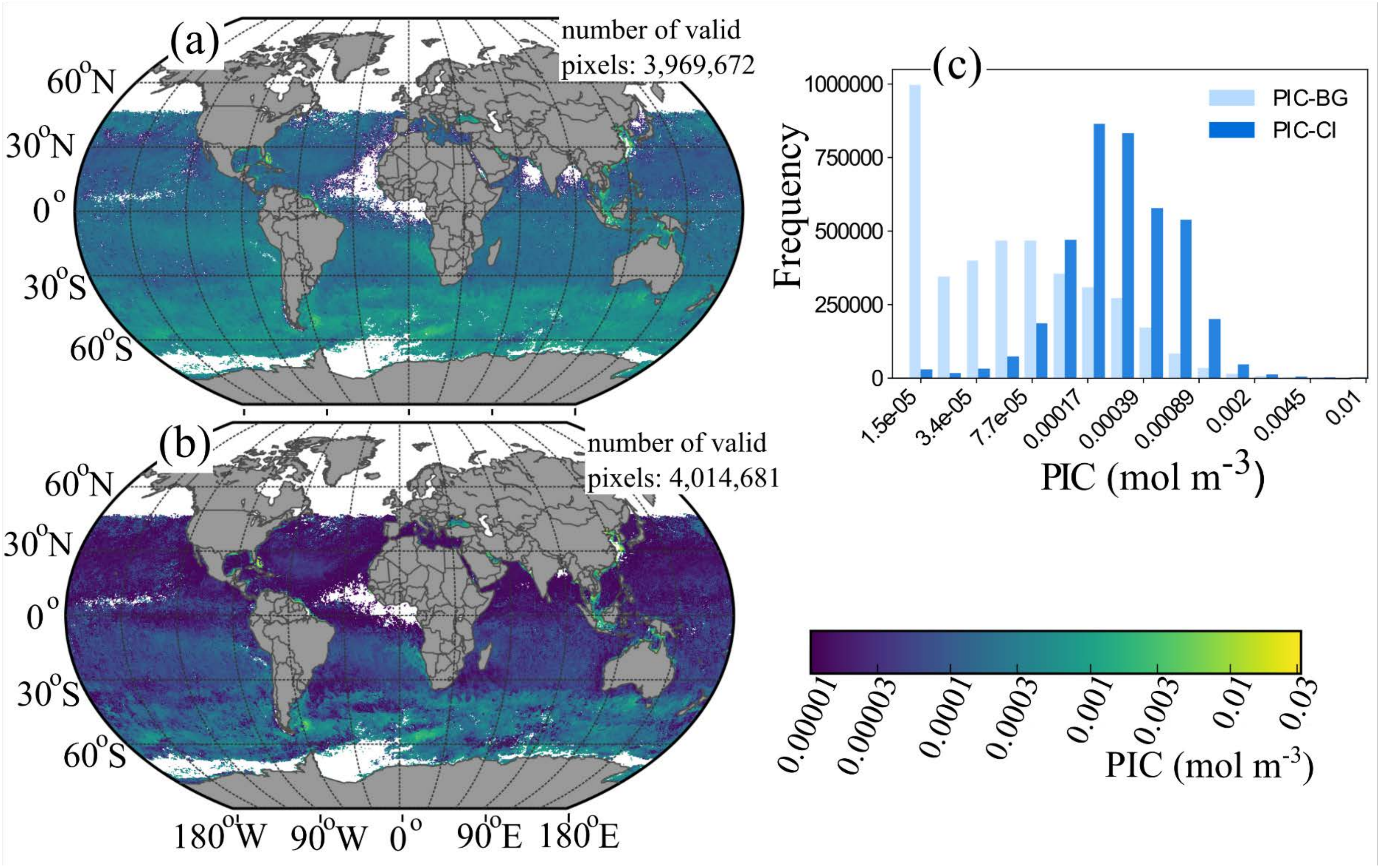
Right: log scale



Updates on PIC algorithm

Algorithm Performance

MODIS PIC in December 2015: Top: CI approach; Bottom: default approach



Updates on POC and PIC algorithms

Summary

POC:

- Color index formed between 490, 555, and 670 appears to outperform B/G ratio algorithms for SeaWiFS, MODIS, and MERIS, especially for high-POC waters
- Additional evaluation using field data and cross-sensor comparison still required
- Le, C., Zhou, X., Hu, C., Lee, Z., Li, L., & Stramski, D. (2018). A color-index-based empirical algorithm for determining particulate organic carbon concentration in the ocean from satellite observations. Journal of Geophysical Research: Oceans, 123, 7407–7419. https://doi.org/10.1029/2018JC014014.

PIC:

- Color index formed between 547, 667, and 754 outperforms the current NASA default
- Algorithm implemented in SeaDAS, and global data available from OC.DAAC as experimental product
- Mitchell, C., C. Hu, B. Bowler, D. Drapeau, and W. M. Balch (2017). Estimating particulate inorganic carbon concentrations of the global ocean from ocean color measurements using a reflectance difference approach. Journal of Geophysical Research: Oceans, 122. https://doi.org/10.1002/2017JC013146

Backup slides

Updates on POC algorithm

Absorption or scattering?

Global *in situ* POC versus (a) satellite-derived $b_b(547)$, and (b) satellite-derived $a(488)$ (N = 849).