Concentrations of multiple phytoplankton pigments in the global oceans obtained from MERIS

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Introduction

The remote sensing of chlorophyll *a* concentration from ocean color satellites has been an essential variable quantifying phytoplankton in the past decades, yet estimation of accessory pigments from ocean color remote sensing data has remained largely elusive. In this study, we validated the concentrations of multiple pigments (chlorophyll *a*, *b*, *c* ([Chl-a], [Chl-b], [Chl-c]), photoprotective carotenoids ([PPC]) and photosynthetic carotenoids ([PSC])) retrieved from *in situ* and MEdium Resolution Imaging Spectrometer (MERIS) measured remote sensing reflectance in the global oceans. These results can greatly expand scientific studies of ocean biology and biogeochemistry of the global oceans that is not possible when the only available information is [Chl-a].

Data

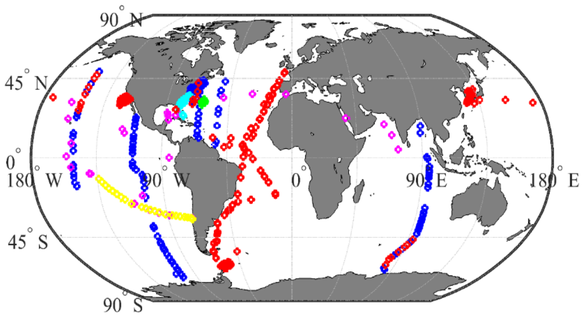

Fig. 1. *In situ* data distribution, the (o) are the stations for SeaBASS $a_{ph}(\lambda)$, (o) are SeaBASS HPLC, (o) are BATS, (o) are BIOSOPE, (o) are VIIRS val/cal, and (o) are for Tara Oceans expedition.

Table 1. All datasets and their parameters.

Datasets	Time	Size (N)	Measurements	Chl-a (mg·m^{-3})
SeaBASS	2001-2012	1619	$a_{ph}(\lambda)$	NA
	1991-2007	430	$a_{ph}(\lambda)$, HPLC	0.02-13.2
IOCCG	NA	500	$R_{rs}(\lambda)$, $a_{ph}(\lambda)$, $a_{dg}(\lambda)$, $b_{bp}(\lambda)$	0.03-30
Tara Oceans	2010-2012	23	$R_{rs}(\lambda)$, $a_{ph}(\lambda)$, HPLC	0.02-0.95
VIIRS cal/val	2014-2015	21	$R_{rs}(\lambda)$, $a_{ph}(\lambda)$, HPLC	0.15-1.5
BIOSOPE	2004	31	$R_{rs}(\lambda)$, $a_{ph}(\lambda)$, HPLC	0.00036-3.06
BATS	2002-2012	148	HPLC	0.002-0.486
MERIS	2002-2012	148	$R_{rs}(\lambda)$	0.037-0.325

Methods

Flow Chart of the main methods

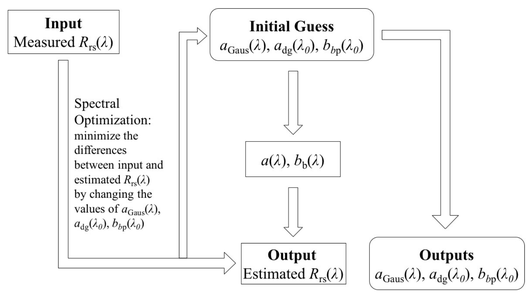

Fig. 2. The spectral optimization method was applied to the semi-analytical algorithm to obtain $a_{Gau}(\lambda)$ from $R_{rs}(\lambda)$.

Pigment concentration estimation

$$\log_{10}(\text{Cpigs}) = a_0 + \sum_{i=1}^{n} a_i \log_{10}\left(a_{\text{Gau}}(\lambda_i)\right)$$

Table 2. Parameters for pigment estimation from $a_{Gau}(\lambda)$.

Pigments	$a_{Gau}(\lambda)$	Parameters (a_0, a_1, …, a_i)	R^2
Chl-a	675	1.804, 0.975	0.889
Chl-b	434, 453, 470	-0.066, 2.470, -3.073, 1.379	0.722
Chl-c	470, 492, 523, 675	1.334, 2.022, -3.125, 0.745, 1.119	0.831
PPC	453, 470	0.734, 1.311, -0.416	0.755
PSC	470, 492, 523	1.67, 3.034, -2.670, 0.725	0.842

Results

Pigments from in situ $R_{rs}(\lambda)$

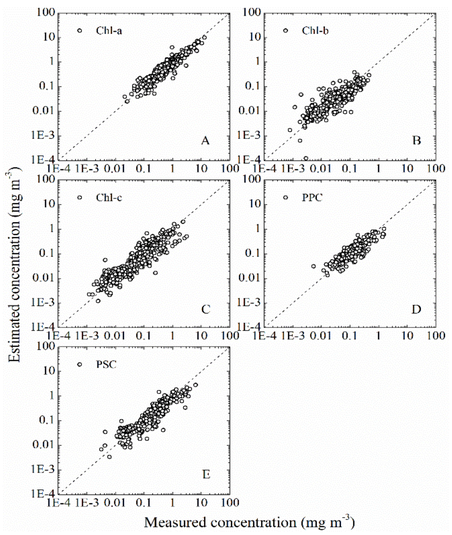

Fig. 3. Pigment concentrations estimated from $a_{Gau}(\lambda)$ versus those from HPLC measurements.

Results

Pigments from MERIS: Bermuda time series

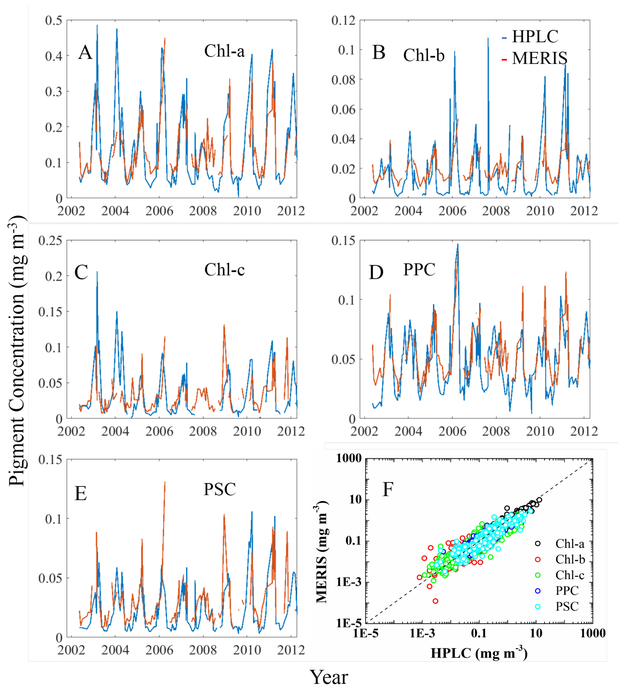

Fig. 4. Time series of pigment concentrations from BATS HPLC and MERIS $R_{rs}(\lambda)$. A: Chl-a: chlorophyll *a*, B: Chl-b: chlorophyll *b*, C: Chl-c: chlorophyll *c*, D: PPC: photoprotective carotenoids, E: PSC: photosynthetic carotenoids, F: the scatterplot of estimated versus in situ pigment concentrations.

Pigments from MERIS: Global oceans

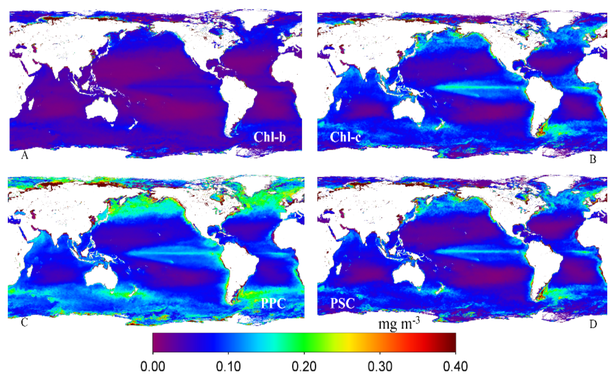

Fig. 5. Global distributions of chlorophyll *b* (Chl-a), chlorophyll *c* (Chl-c), photoprotective carotenoids (PPC) and photosynthetic carotenoids (PSC) from 2007 L3 annual MERIS $R_{rs}(\lambda)$ imagery.

Pigment to Chl-a ratios

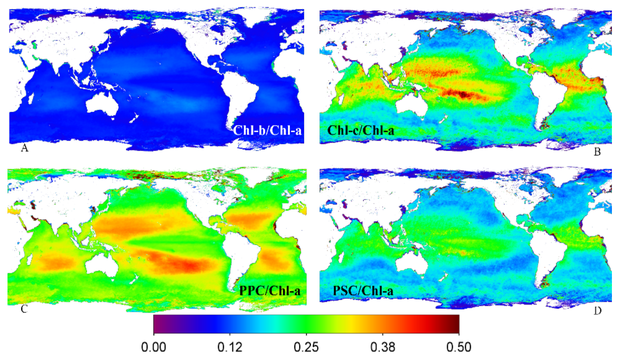

Fig. 6. Global distributions of the accessory pigment to chlorophyll *a* ratios.

Comparison with NASA standard product

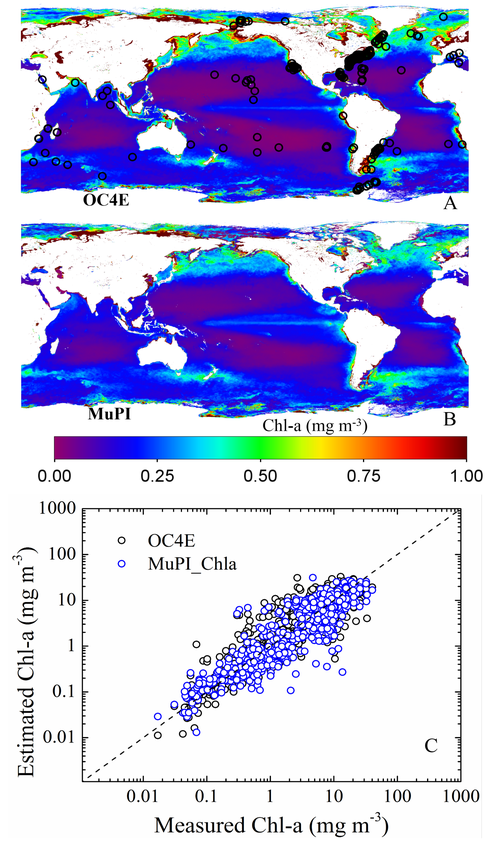

Fig. 7. Global distributions of chlorophyll *a* concentration estimated from 2007 MERIS L3 $R_{rs}(\lambda)$ imagery using NASA standard algorithm OC4E (top) and MuPI model (bottom).

Conclusions

1. Good agreement has been achieved in comparison of the MERIS estimated pigment concentrations with HPLC measurements.
2. MERIS estimated pigment concentrations picked up the seasonal variation of the pigments from Bermuda Atlantic Time-series Study (BATS).
3. The distribution and variation of pigment ratios in the global oceans are picked up by MERIS imagery.
4. The information of the accessory pigments would extend the application of satellite ocean color data in global biogeochemical studies that was previous limited due to [Chl-a] as the only available pigment.

References

Wang, G., Lee, Z., Mishra, D. R., & Ma, R. (2016). Limnology and Oceanography: Methods. doi: 10.1002/lom3.10102

Wang, G., Lee, Z., & Mouw, CW. (2017). Remote Sensing. doi:10.3390/rs9121309

Acknowledgements

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