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 $a_{\text{SPC}}(\lambda)$, (x) are SeaBASS HPLC, (o) are BATS, (x) are VIIRS val/cal, and (o) are for Tara Oceans expedition.

Methods

Flow Chart of the main methods

![Flow Chart](flow_chart.png)

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

Pigment concentration estimation

$$\log_{10}(C_{\text{pig}}) = a_0 + \sum \log_{10}(a_{\text{out}}(\lambda_i))$$

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

<table>
<thead>
<tr>
<th>Pigments</th>
<th>$a_{\text{out}}(\lambda)$</th>
<th>Parameters ($a_0, a_1, \ldots, a_7$)</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chl-$a$</td>
<td>675</td>
<td>1.804, 0.975</td>
<td>0.889</td>
</tr>
<tr>
<td>Chl-$b$</td>
<td>434, 453, 470</td>
<td>-0.066, 2.470, 3.073, 1.379</td>
<td>0.722</td>
</tr>
<tr>
<td>Chl-$c$</td>
<td>470, 492, 523, 675</td>
<td>1.334, 2.022, -3.125, 0.745, 1.119</td>
<td>0.831</td>
</tr>
<tr>
<td>PPC</td>
<td>453, 470</td>
<td>0.734, 1.311, -0.416</td>
<td>0.755</td>
</tr>
<tr>
<td>PSC</td>
<td>470, 492, 523</td>
<td>1.67, 3.034, -2.670, 0.725</td>
<td>0.842</td>
</tr>
</tbody>
</table>

Results

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

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

Pigments from MERIS: Bermuda time series

![Time series](time_series.png)

Fig. 4. Time series of pigment concentrations from BATS HPLC and MERIS $R_{\text{in}}(\lambda)$. 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

![Global distributions](global_distributions.png)

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

Pigment to Chl-$a$ ratios

![Pigment to Chl-$a$ ratios](pigment_to_chl-a.png)

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

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


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