VIIRS-derived Chlorophyll-a using the Ocean Color Index method

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INTRODUCTION

- For satellite ocean color remote sensing, phytoplankton chlorophyll-a (Chl-a) concentrations are generally measured using empirical regressions of spectral ratios of normalized water-leaving reflectances (or remote sensing reflectances).
- Widely used Chl-a algorithm for the ocean color satellite sensors such as SeaWiFS, MODIS, & VIIRS is based on the ocean chlorophyll-type (OCx) (*O'Reilly et al.*, 1998) (e.g., OC3V for VIIRS).
- The band ratio-based Chl-a algorithm can have considerable noise errors for oligotrophic waters (Hu et al., 2012). A new Chl-a algorithm based on the color index (CI) has been developed (Hu et al., 2012).
- The CI-based Chl-a algorithm can improve VIIRS Chl-a data over oligotrophic waters with much reduced data noise from instrument calibration and the imperfect atmospheric correction.
- However, the CI-based Chl-a algorithm is only applicable for low Chl-a concentration (< ~0.3 mg m^{-3}). A merging method between CI-based and OCx Chl-a algorithms has been proposed based on Chl-a concentration.
- All coefficient related to the CI-based Chl-a algorithm need to be re-derived for VIIRS spectral bands.
- It is noticed that there are obvious discontinuities for VIIRS Chl-a data in the Chl-a transition between the two algorithms.

OBJECTIVES

- To Evaluate Performance of the original OCI-derived Chl-a products from VIIRS measurements with comparison of the VIIRS OC3V-derived Chl-a products for the global ocean.

- To Improve the CI-based Chl-a algorithm for VIIRS spectral bands and to be overall consistent with the OC3V-derived Chl-a data.

- To develop a new merging method for the two Chl-a algorithms between CI-based and OC3V algorithms.

- To Implement the newly improved OCI-based Chl-a algorithm to the VIIRS ocean color products.

MOBY In Situ Measurements

- In situ hyperspectral radiometeric measurements at the MOBY site moored off the island of Lanai in Hawaii (*Clark et al.*, 1997) were used.
- VIIRS spectral-band-weighted MOBY in situ normalized water-leaving radiance, $nL_w(\lambda)$, data at 410, 443, 486, 551, and 671 nm are obtained from the NOAA CoastWatch website (http://coastwatch.noaa.gov/moby/).
- MOBY-derived Chl-a data using the CI-based and OC3V-based Chl-a algorithms were compared with VIIRS-derived Chl-a data to evaluate performance of the CI-based Chl-a algorithm.

Satellite Ocean Color Data

- NOAA Multi-Sensor Level-1 to Level-2 (MSL12) ocean color data processing system has been used for processing satellite ocean color data from Level-1B to Level-2.
- **Science Quality VIIRS ocean color product data** were generated using NOAA-MSL12. VIIRS ocean color Environmental Data Records (EDR) (or Level-2) were processed from the improved Sensor Data Records (SDR) (or Level-1B) (*Sun & Wang*, 2015).
- The VIIRS EDR data were derived using the NIR-SWIR combined atmospheric correction algorithm.
- VIIRS ocean color Level-3 data products for the global ocean were processed from the VIIRS-derived Level-2 products with a spatial resolution of 9 km.
- Matchups of VIIRS and in situ Chl-a data were developed using pixels with a 5 × 5 box centered at the location of in situ measurements following the procedure of *Wang et al.* (2009).

OCx Based Chl-a Algorithm

- **OC3V** Chl-a algorithm for **VIIRS**

$$\text{Chl-a} = 10\wedge[a_0 + a_1 \cdot \boldsymbol{R} + a_2 \cdot \boldsymbol{R}^2 + a_3 \cdot \boldsymbol{R}^3 + a_4 \cdot \boldsymbol{R}^4]$$

where $\boldsymbol{R} = Log_{10}\{\ \text{Max}[R_{rs}(443), R_{rs}(486)] / R_{rs}(551)\ \}$

$a = [0.2228, -2.4683, 1.5867, -0.4275, -0.7768]$

Color Index based Chl-a Algorithm

- Color Index based Chl-a algorithm (*Hu et al.*, 2012):

$$CI = R_{rs}(555) - [R_{rs}(443)+(B_2-B_1)/(B_3-B_1)(R_{rs}(670)-R_{rs}(443)]$$

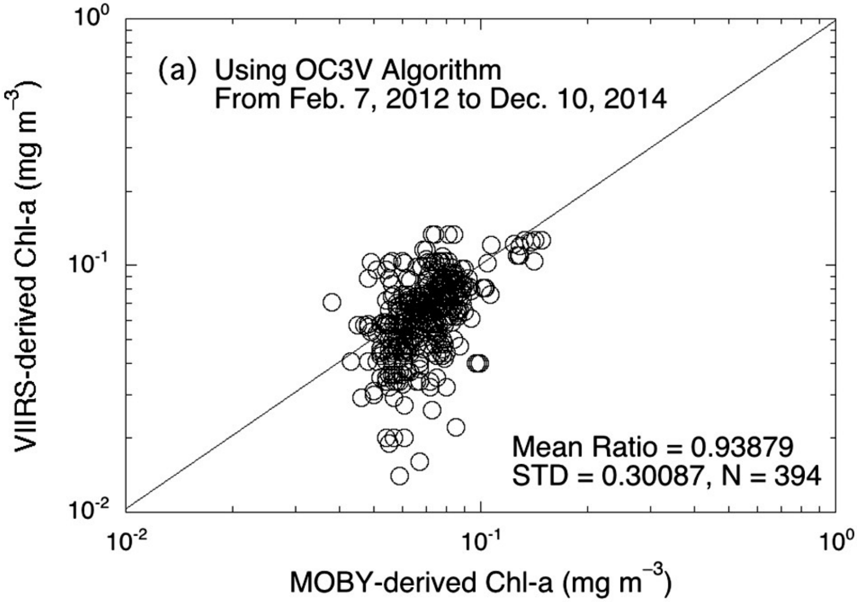
where $B_1=443$, $B_2=555$, $B_3=670$

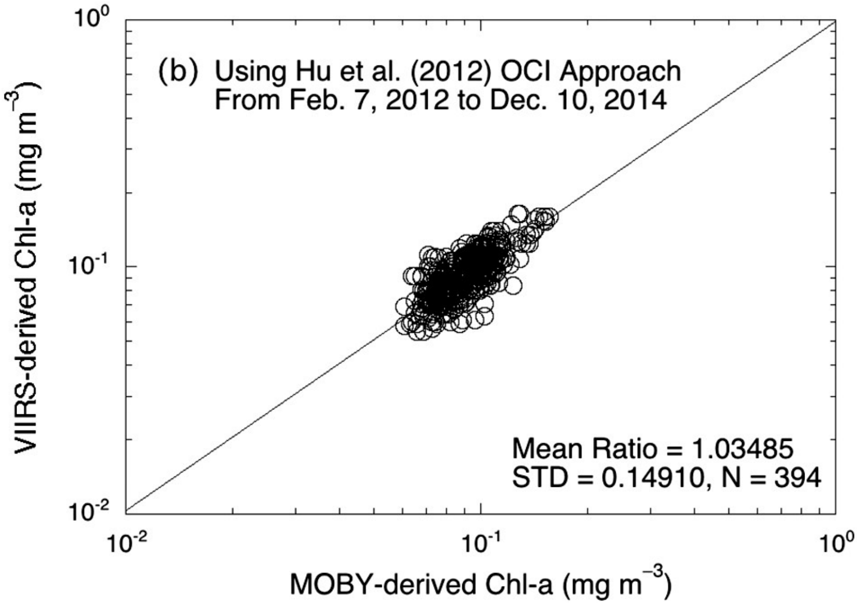
$$Chl_{CI} = 10\text{^}[191.6590 \cdot CI - 0.4909] \qquad (CI \leq -0.0005\ sr^{-1})$$

$$Chl_{OCI} = \begin{cases} Chl_{CI} & (CHL_{CI} \leq 0.25\ mg\ m^{-3}) \\ Chl_{OC4} & (CHL_{CI} > 0.30\ mg\ m^{-3}) \\ \alpha \times Chl_{OC4} + \beta \times Chl_{CI} & (0.25\ mg\ m^{-3} < CHL_{CI} \leq 0.30\ mg\ m^{-3}) \end{cases}$$

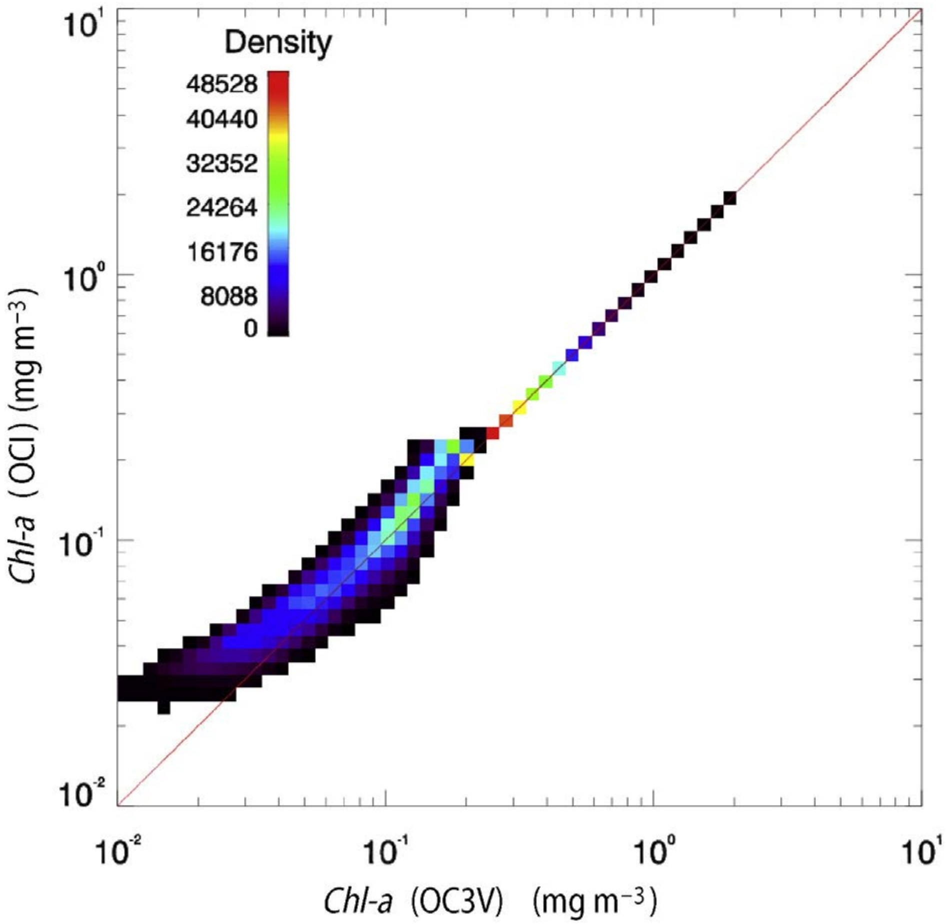
where $\alpha=(Chl_{CI}-0.25)/(0.3-0.25)$ and $\beta=(0.3- Chl_{CI})/(0.3-0.25)$

VIIR-derived Chl-a data compared with those derived from the in situ MOBY data





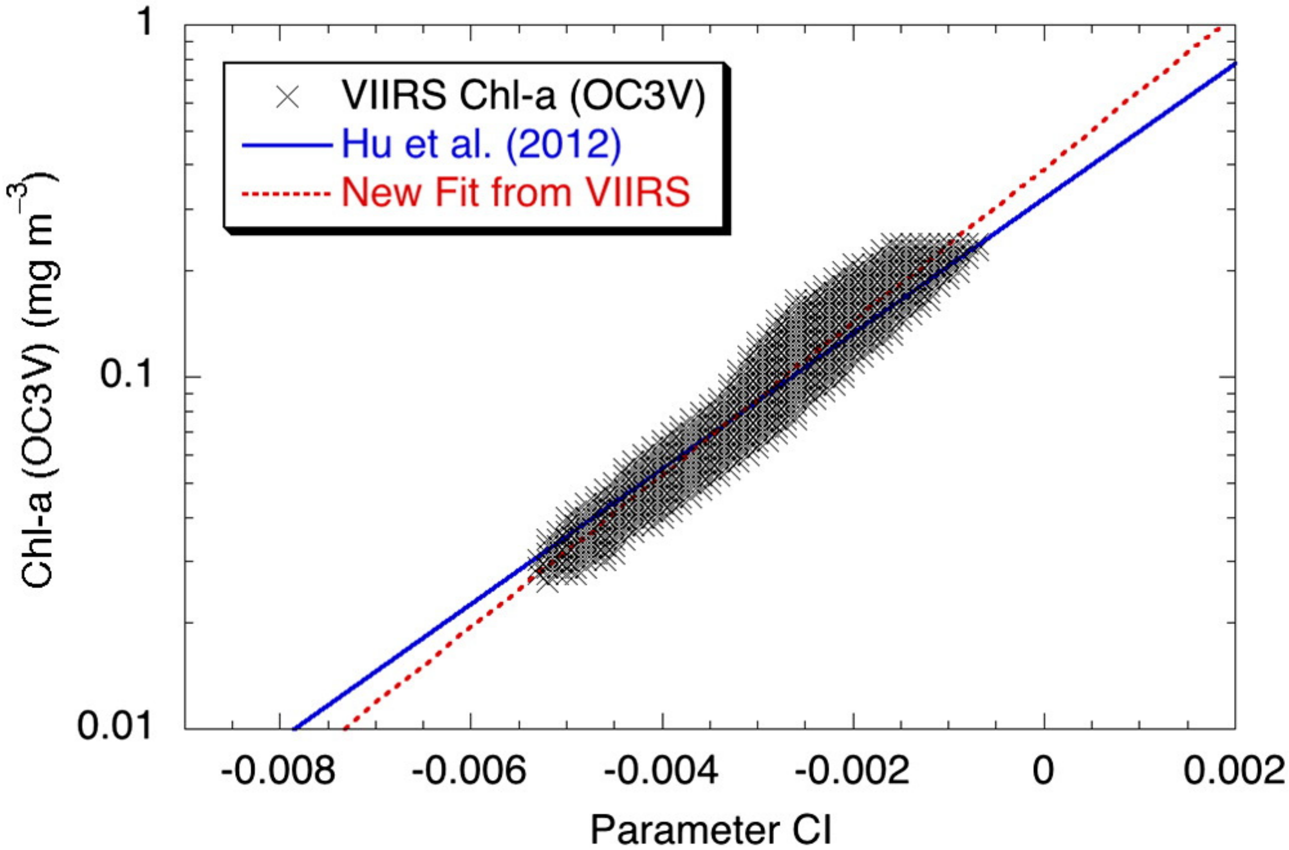
Density Scatter plot for VIIRS-derived Chl-a using OC3V and OCI Chl-a algorithms



-. Global (binned) VIIRS Level-3 daily data on March 29, 2015

-. Only pixels with water depths > 1 km are used

Scatter plot for VIIRS-derived Chl-a with OC3V vs CI values



-. All the data in the plot were extracted from the density plot that requires density > 5000 pixels.

New OCI Chl-a Algorithm

- **New OCI Chl-a algorithm for VIIRS ocean color data:**

$$CI = R_{rs}(551) - [R_{rs}(443)+(B_2-B_1)/(B_3-B_1)(R_{rs}(671)-R_{rs}(443)]$$

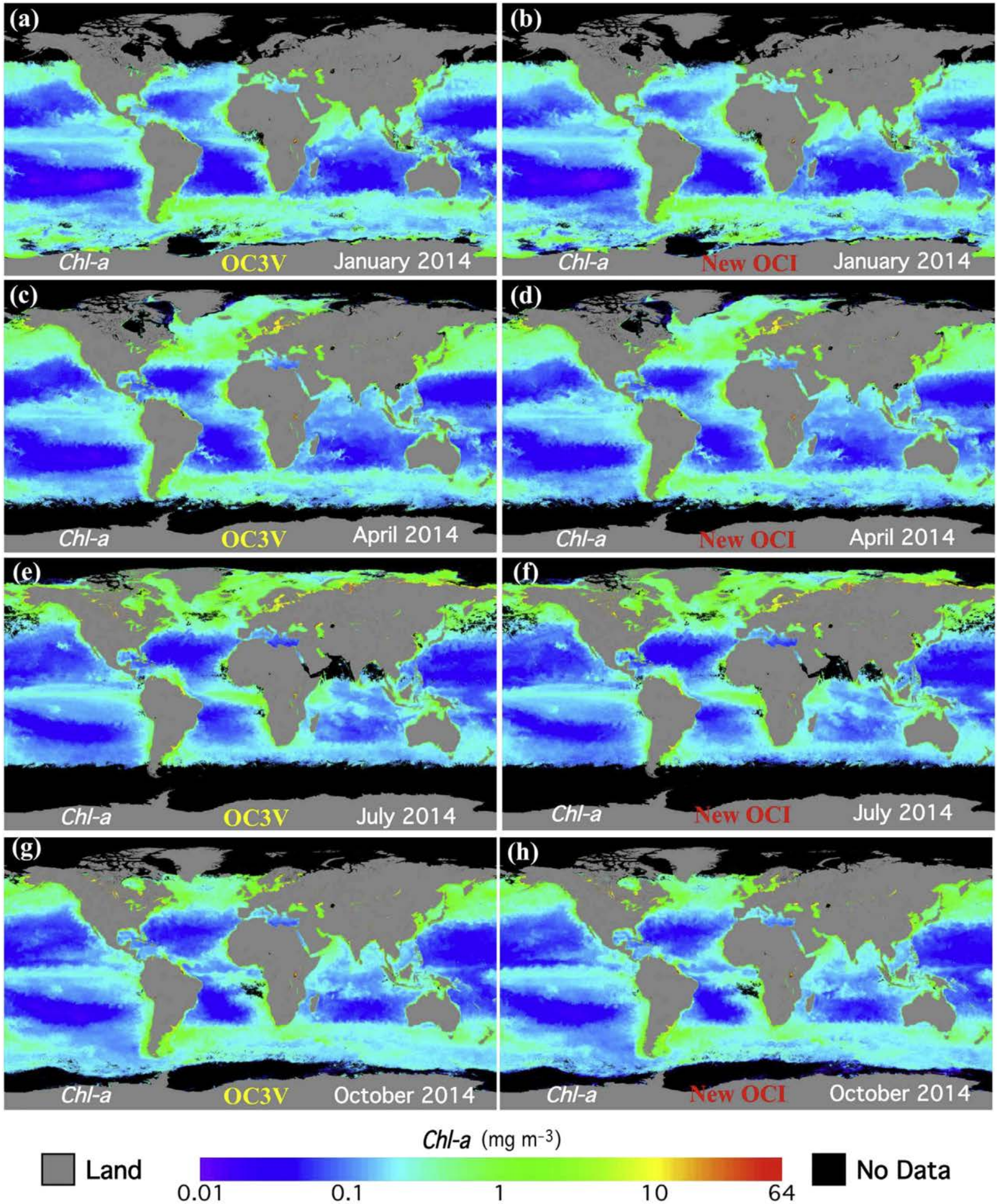
where $B_1=443$, $B_2=551$, $B_3=671$

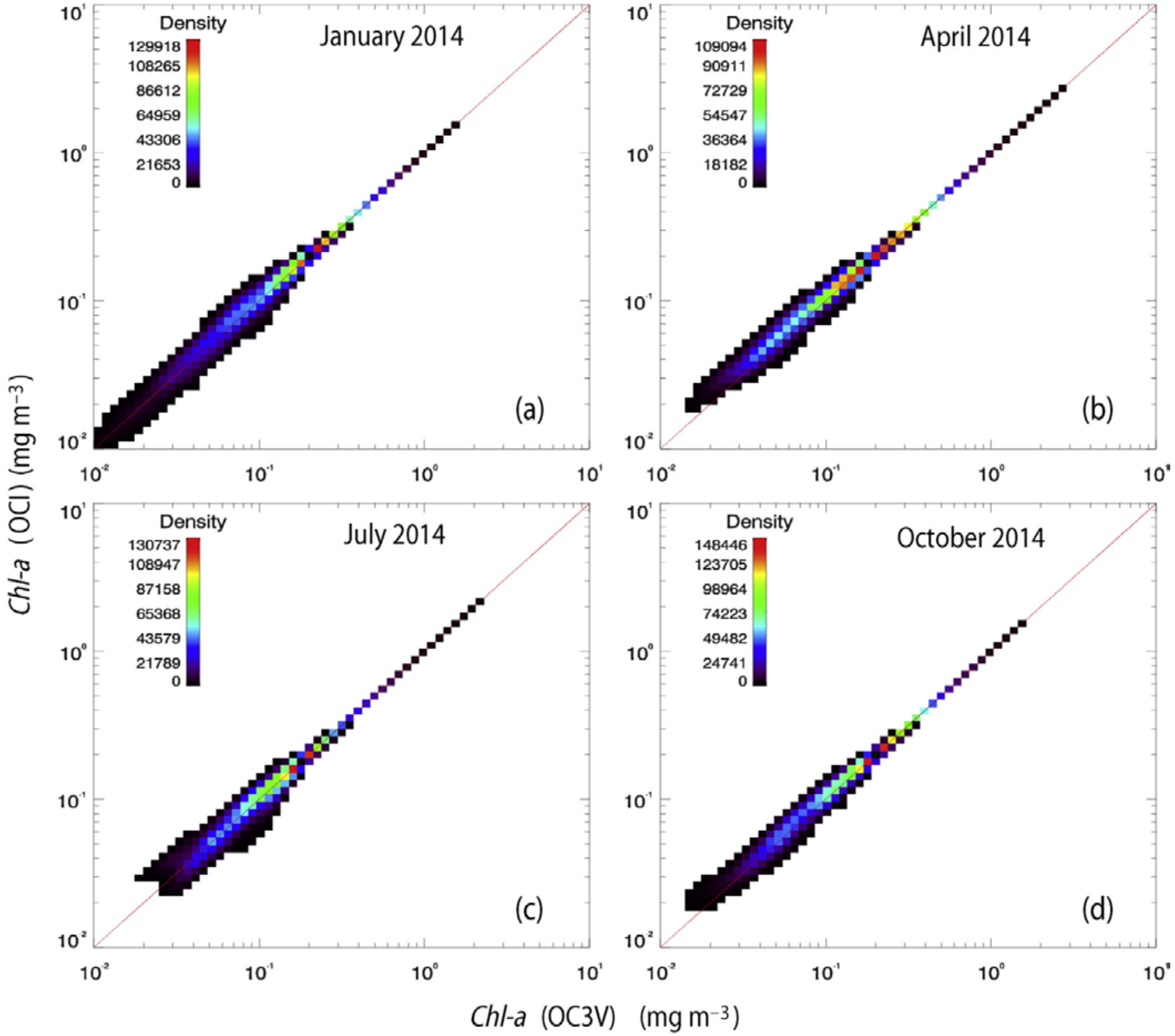
$$Chl_{CI} = 10\text{^}[216.76 \cdot CI - 0.4093]$$

$$Chl_{OCI} = \begin{cases} Chl_{OC3V} & (R \le 2.0) \\ Chl_{OC3V} & (R > 4.0) \\ w \times Chl_{CI} + (1-w) \times Chl_{OC3V} & (2.0 < R \le 4.0) \end{cases}$$

where $R=R_{rs}(443)/R_{rs}(551)$ & $w=(R-2.0)/(4.0-2.0)$

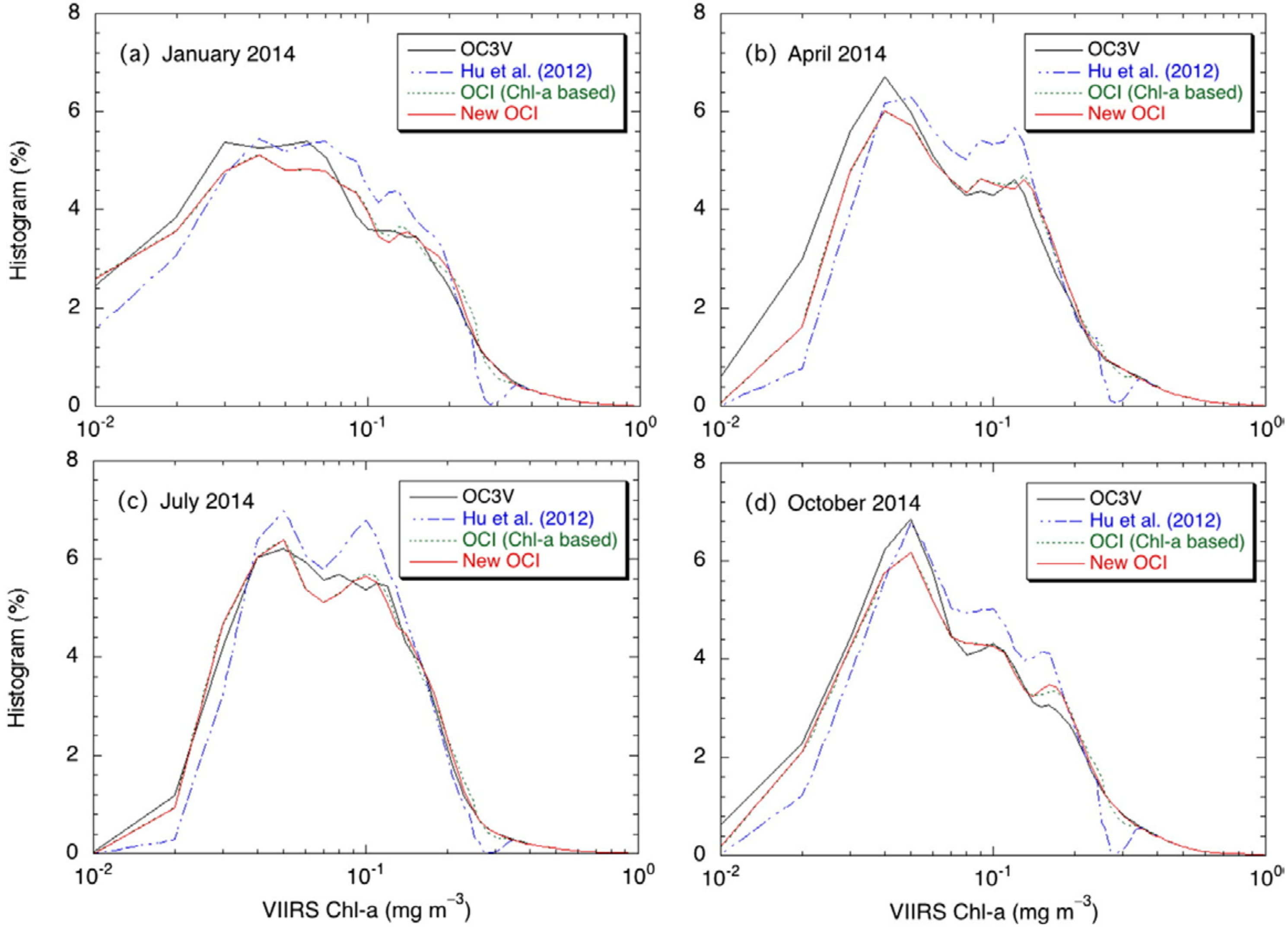
VIIRS-derived global Chl-a monthly composite images



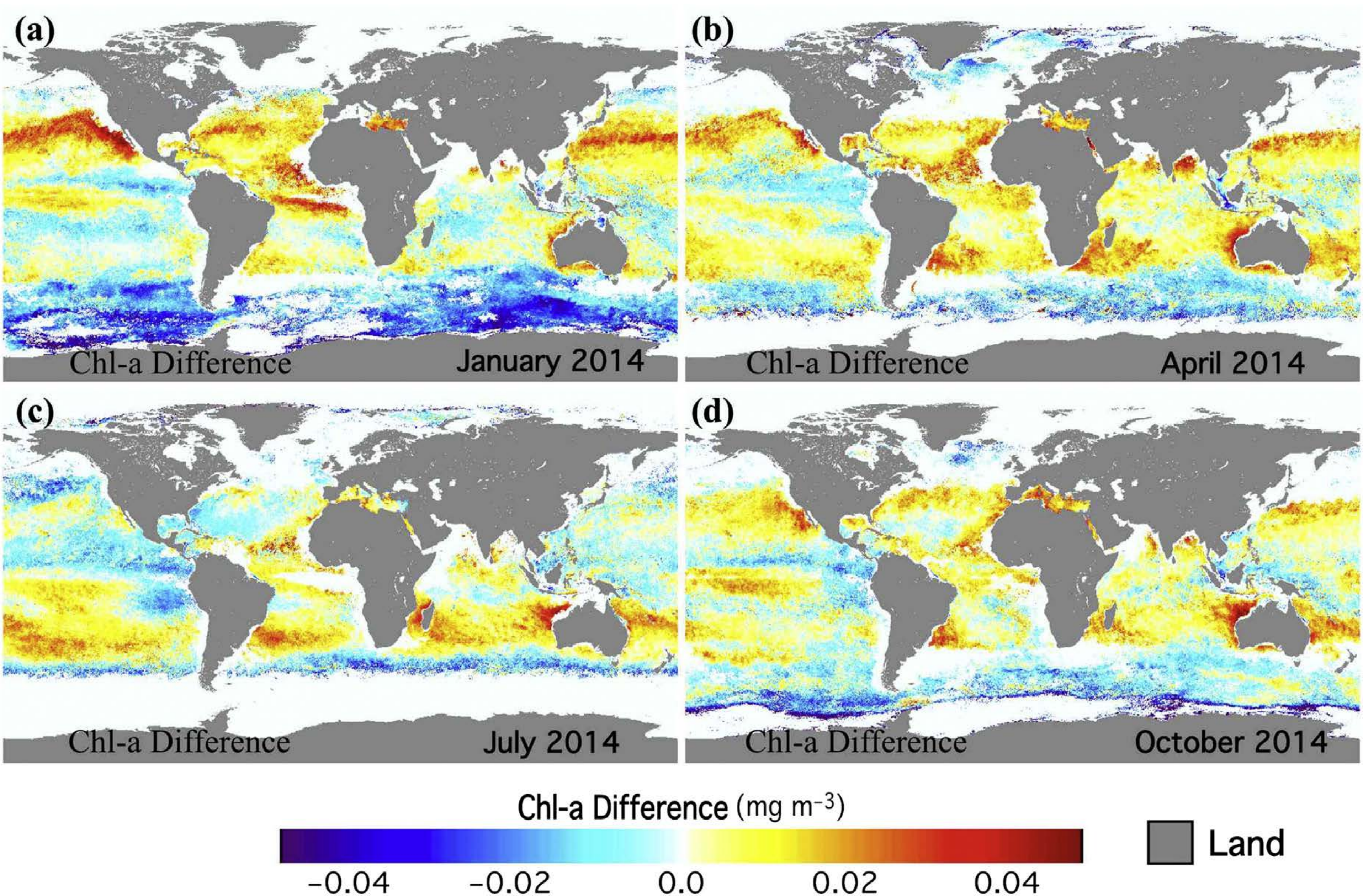


Density scatter plots of global VIIRS Level-3 monthly composite Chl-a images

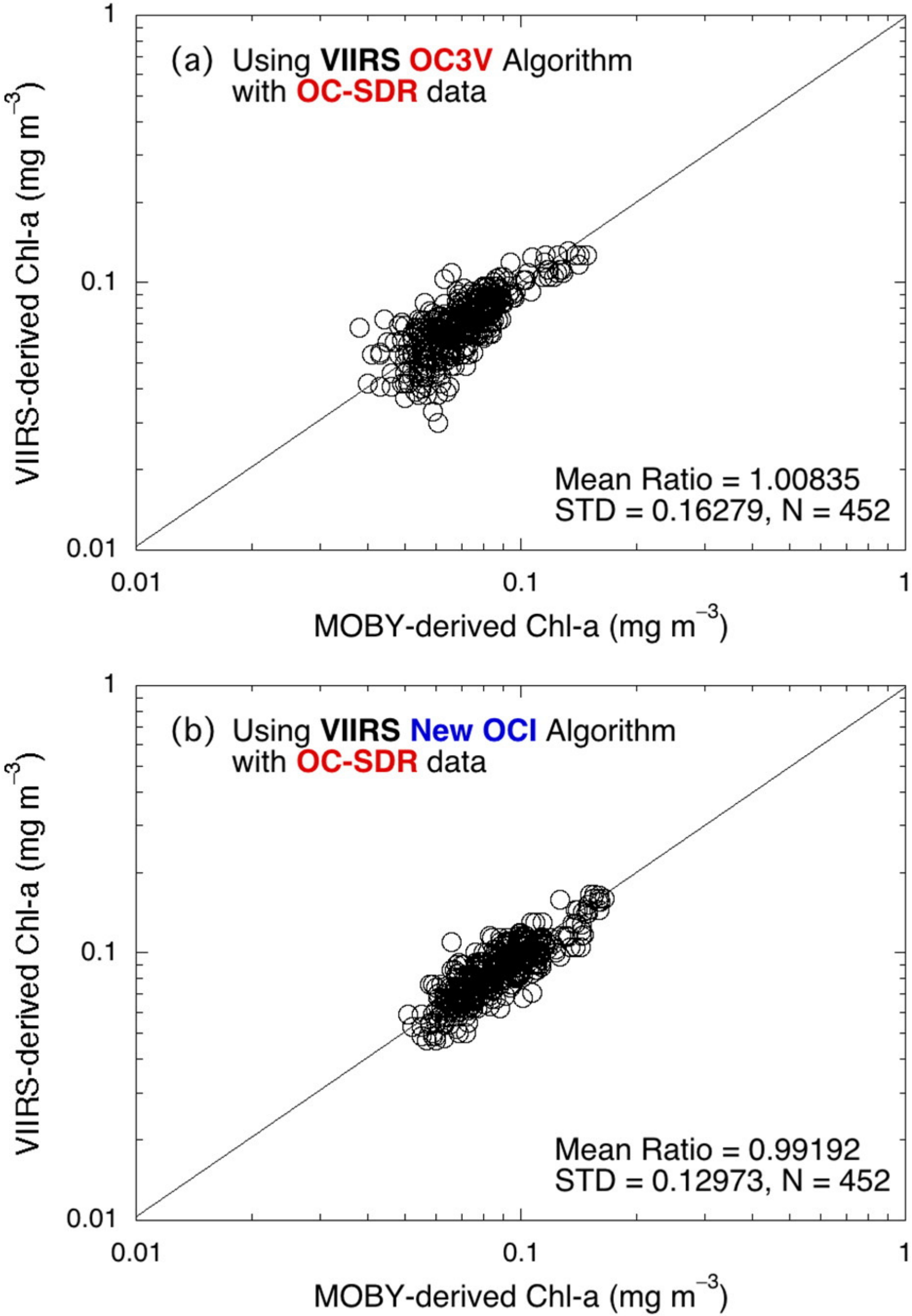
Histogram plots of VIIRS global Level-3 monthly composite Chl-a data



Global images of Chl-a difference between new OCI and OC3V Chl-a data



VIIR-derived Chl-a data compared with those derived from the in situ MOBY data



Conclusions

- An implementation approach using the ocean color index (OCI)-based chlorophyll-a (Chl-a) algorithm for the VIIRS has been developed.
- The CI-based Chl-a algorithm can improve VIIRS Chl-a data over oligotrophic waters with much reduced data noise from instrument calibration and the imperfect atmospheric correction.
- We developed CI-based algorithm specifically for VIIRS and further improved the two Chl-a algorithm merging method using the blue-green reflectance ratio values.
- New OCI Chl-a algorithm for VIIRS can produce consistent Chl-a data compared with those from the OC3V algorithm.
- In particular, the data transition between CI-based and OC3V-based Chl-a algorithms is quite smooth and there are no obvious discontinuities in VIIRS-derived Chl-a data.
- New OCI-based Chl-a algorithm has been implemented in the MSL12 for routine production of VIIRS global Chl-a data.
- A paper has just been published:

Wang, M. and S. Son, "VIIRS-derived chlorophyll-a using the ocean color index method," *Remote Sens. Environ.*, **182**, 141–149, 2016.

Thank you!