Characterization of Optical Attenuation by Colored Dissolved Organic Matter (CDOM) in the Red Sea

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Abstract: Optical properties of colored dissolved organic matter (CDOM) control the downward irradiance in the ultraviolet and visible range of the electromagnetic radiation. CDOM is a strong absorber in shorter wavelengths (ultraviolet light) with steeper spectral slopes in the open ocean. Despite the importance of CDOM in understanding physical and biogeochemical processes in the marine environment, *in situ* measurements of optical properties in the Red Sea are sparse. This study comprises CDOM absorption from two different instruments (i.e. a spectrophotometer and WET Labs ac-s sensor), and assesses the variations in optical properties of CDOM in the Red Sea using data collected in 2014 and 2015. Three global inversion algorithms (Garver-Siegel-Maritorena model - GSM, Quasi-Analytical Algorithm - QAA, and the Constrained Linear-Matrix inversion model - CLM) were applied to recent data collected in the Red Sea, providing the comparison at five key selected wavelengths (412, 443, 490, 510, and 555 nm) demonstrated that *in situ* a_{CDOM} values were higher than the values predicted from the three inversion algorithms and leads to underestimating *in situ* measurements. This finding is consistent with the conclusion of Brewin et al. (2015) that overestimation of chlorophyll in the Red Sea could be due to excessive CDOM.

Study Area

The Red Sea, situated between Africa and Arabian Peninsula, is long and narrow (250km x 2000km) and one of the warmest and saltiest seas on Earth. It is considered an oligotrophic water body with low nutrient and chlorophyll concentrations. Coral reefs line its coastal boundaries. It receives significant atmospheric dust deposition, and eddies are prevalent throughout the sea.

Until recently, satellite remote sensing was one of the main sources of data used to study the large-scale physical and biological processes in the Red Sea (Acker et al., 2008; Raitos et al., 2013; Brewin et al. 2013; Brewin et al., 2015).

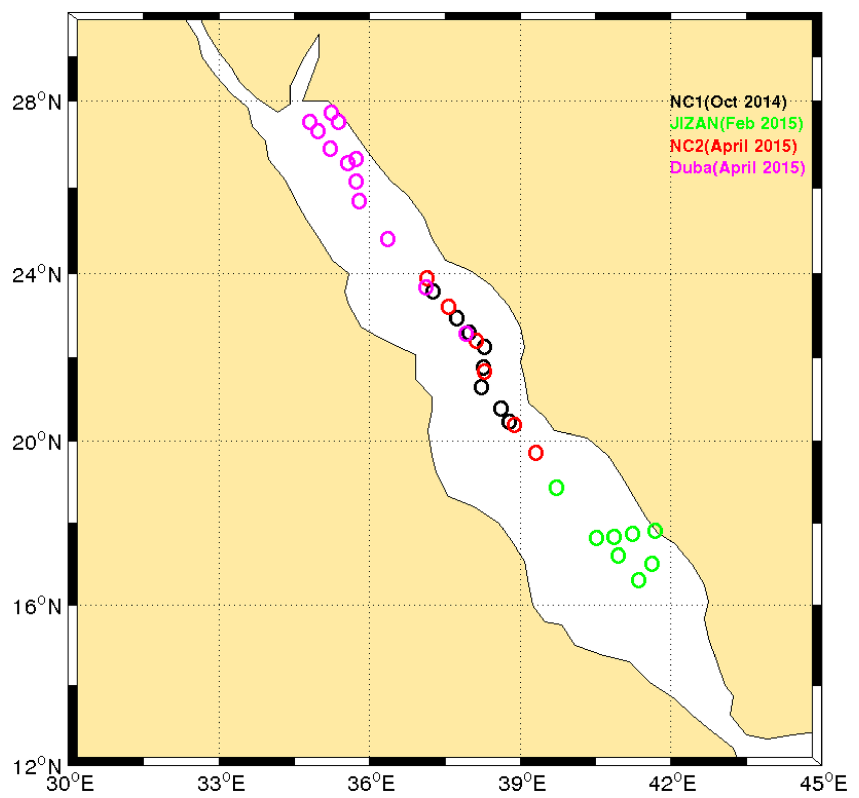

Fig. 1. Study area and sample locations in the Red Sea.

Objectives

The present study aims (1) to understand the optical variability of CDOM absorption and its spectral slope in the Red Sea, and (2) to evaluate standard global inversion algorithms for estimating CDOM absorption coefficients from remote-sensing reflectance.

Datasets

- We have used *in situ* data from two different instruments, i.e. spectrophotometric CDOM absorption and CDOM absorption from ac-s.
- Apparent optical properties were measured using a Satlantic™ HyperPro-II in free fall profiler mode.
- Remote sensing reflectance (R_{rs}) was calculated using Prosoft 7.7.16_6 (www.satlantic.com).
- S_{CDOM} values were obtained from a nonlinear least-square fit on the absorption spectra to an exponential function from 300 to 650 nm (Twardowski et al., 2004).

Results

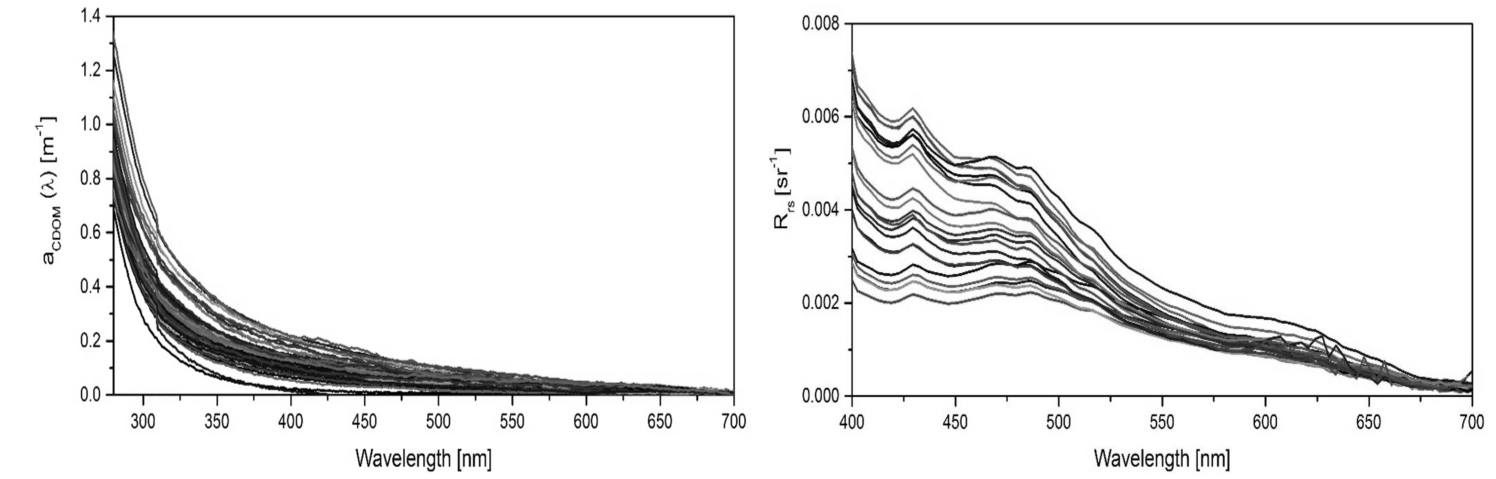

Fig. 2. Examples of CDOM absorption and remote sensing reflectance spectra in the Red Sea. The $a_{CDOM}(\lambda)$ spectra with high absorptions in the shorter wavelength with exponentially decreasing toward the longer wavelengths.

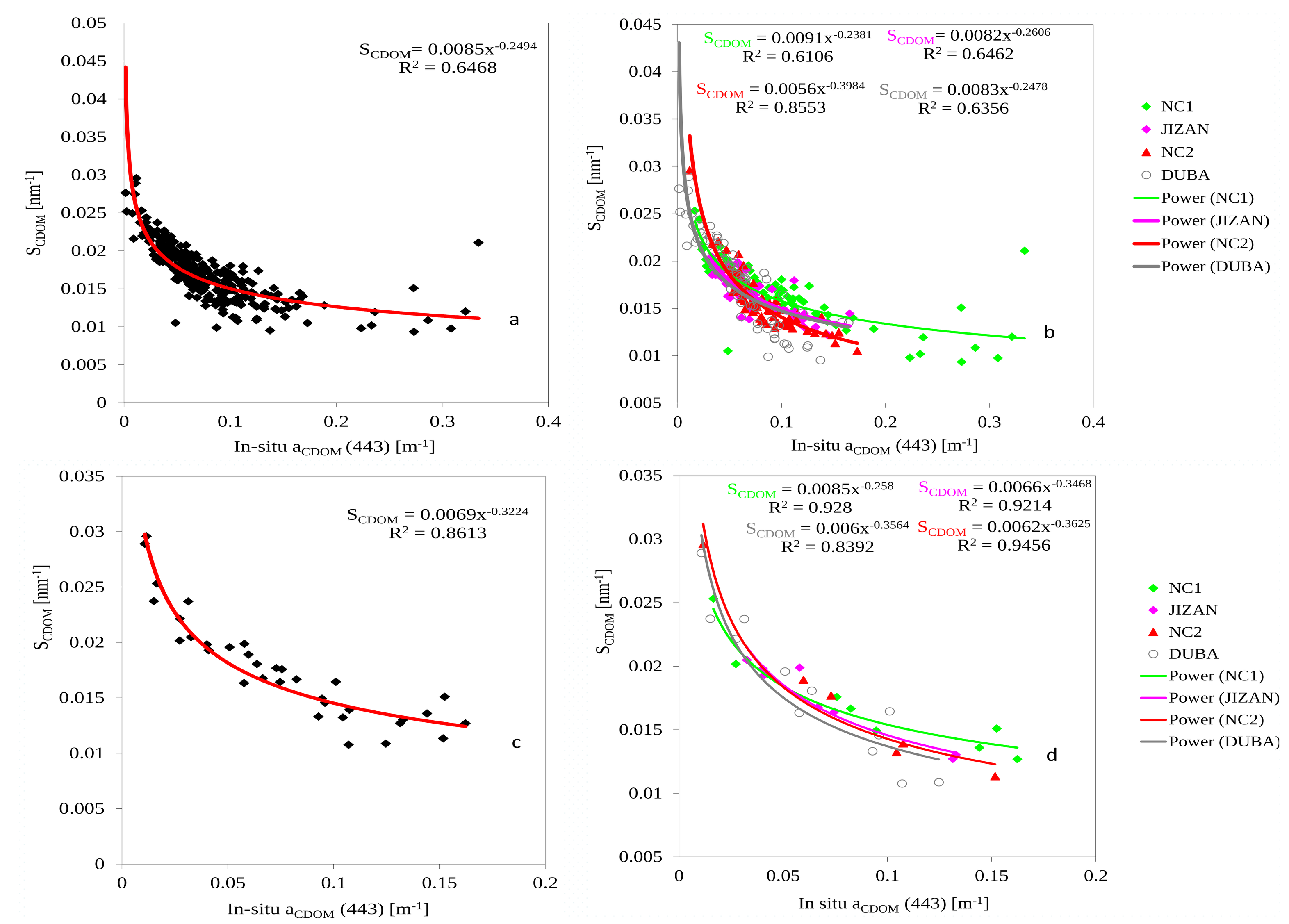

Fig. 3. (a & b) Relationships between the S_{CDOM} and *in situ* $a_{CDOM}(443)$; surface and subsurface data are considered; N = 270), and (c & d) relationships between the surface S_{CDOM} versus surface *in situ* $a_{CDOM}(443)$ for the Red Sea (N = 34).

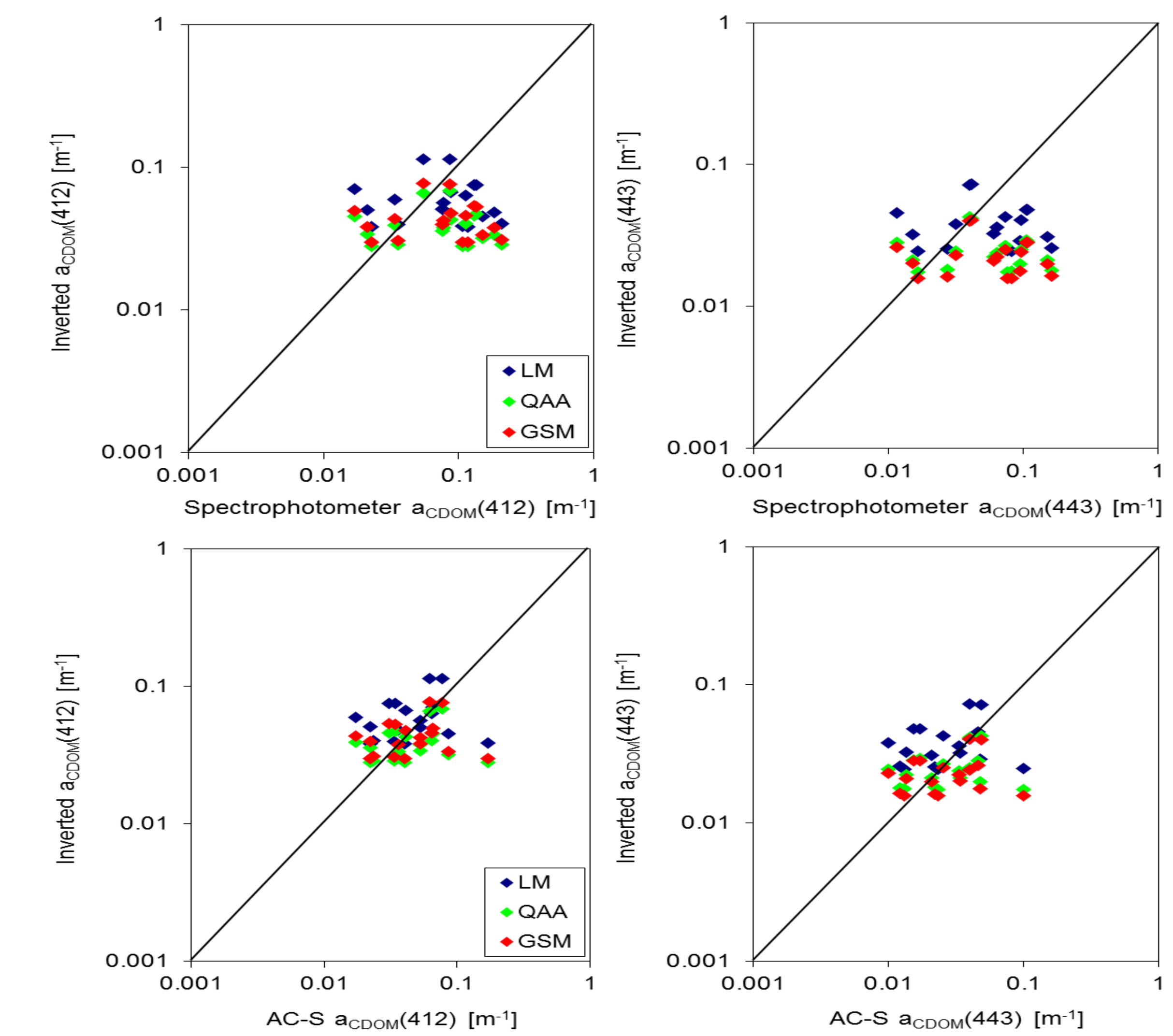

Fig. 4. Comparison of the inverted (LM-Constrained Linear Matrix model (LM), QAA-Quasi Analytical Algorithm (QAA), and Garver-Siegel-Maritorena (GSM), $a_{CDOM}(\lambda)$ and in-situ $a_{CDOM}(\lambda)$ values from spectrophotometer and ac-s at two key selected wavelengths (for brevity; N = 18).

Conclusions

- Surface and subsurface spectral slope values are well correlated with the CDOM absorption at 443 nm in the different parts of the Red Sea.
- For all depth data (N=270) S_{CDOM} varied from **0.01 to 0.030 nm^{-1}**, with an average slope of **0.017 nm^{-1}** and standard deviation of 0.004 nm^{-1}.
- Higher amounts of CDOM significantly influence the retrieval of ocean color estimates.
- High values of spectral slopes occur in the northern Red Sea where Chl *a* concentration and productivity is typically low and salinity is maximal for the Red Sea.
- A narrow range of spectral slopes value characterizes the southern Red Sea.
- CDOM slopes were varied more in the Northern Red Sea and showed less variability in the Southern part of the Red Sea.
- Future study will be focused on the sources and sinks of CDOM in the Red Sea.

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