Diffuse Attenuation Coefficient of the Photosynthetically Available Radiation (PAR), $K_d$(PAR), for Global Open Ocean and Coastal Waters

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Website for VIIRS ocean color images, data and Cal/Val:  
http://www.star.nesdis.noaa.gov/sod/mecb/color/

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Motivation

- Light penetration and availability in the ocean waters have tremendous importance in surface heat budgets and biological productions in the marine ecosystem.

- Satellite ocean color observations such as SeaWiFS, MODIS, and VIIRS can be used to provide estimations of diffuse attenuation coefficients at 490 nm, $K_d(490)$.

- There is a need for a satellite-derived diffuse attenuation coefficient for the photosynthetically available radiation (PAR), $K_d(PAR)$, for oceanic and atmospheric circulation models, e.g., $K_d(PAR)$ is one of the required inputs to the HYCOM used in NOAA/NCEP.

- Studies have shown that there are robust relations between $K_d(490)$ and $K_d(PAR)$ in various ocean waters, but the relationship varies regionally with a wide range. Thus we need to improve $K_d(PAR)$ model for both open ocean and coastal waters.
Objectives

- Examine the performance of some existing $K_d$(PAR) models using in situ measurements.

- Propose and assess a new blended method of $K_d$(PAR) model for both open oceans and turbid coastal waters.

- Provide the satellite-derived $K_d$(PAR) images from the MODIS-Aqua and VIIRS ocean color products using the new blended $K_d$(PAR) model.
- NASA SeaBASS data (http://seabass.gsfc.nasa.gov/) including $nL_w(\lambda)$, $K_d(\lambda)$ and $K_d$(PAR) collected from 1995 to 2009 are used.

- In addition, $K_d$(PAR) data obtained from the Chesapeake Bay Program Water Quality Database (http://www.chesapeakebay.net/wquality.htm) were used for validation and evaluation of the MODIS-Aqua-derived $K_d$(PAR) products.
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. MSL12 is the official JPSS ocean color data processing system.

- MODIS-Aqua ocean color products were generated using NOAA-MSL12 with the NIR-SWIR combined atmospheric correction algorithm (Wang, 2007; Wang & Shi, 2007). MODIS-Aqua Level-1B data were obtained from the NASA MODAPS Service website (http://modaps.nascom.nasa.gov/).

- Matchups of MODIS and in situ $K_d$(PAR) data were developed using pixels with a $5 \times 5$ box centered at the location of in situ measurements following the procedure of Wang et al. (2009).

- VIIRS ocean color product data were also derived using NOAA-MSL12. VIIRS ocean color Environmental Data Records (EDR) (or Level-2) were processed from the Sensor Data Records (SDR) (or Level-1B).

- 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.
SeaBASS $K_d(\lambda)$ Spectra
Conversion from $K_d(490)$ to $K_d$(PAR)

- For open ocean waters:

  \[ K_d\text{(PAR)} = 0.0864 + 0.8 \ K_d\text{(490)} - 0.00137 \ K_d\text{(490)}^{-1} \]

  (Morel et al., 2007)

- For turbid coastal waters:

  \[ K_d\text{(PAR)} = 0.8045 \ K_d\text{(490)}^{0.917} \]

  (Wang et al., 2009)

- For CDOM-dominated waters:

  \[ K_d\text{(PAR)} = 0.6677 \ K_d\text{(490)}^{0.6763} \]

  (Pierson et al., 2008)

  \[ K_d\text{(PAR)} = K_d\text{(490)} / 1.48 \]

  (Kratzer et al., 2003)
In situ $K_d$(PAR) measurements compared with in situ $K_d$(490) data from the SeaBASS database (unit: m$^{-1}$).
Model-derived $K_d$(PAR) vs. SeaBASS in situ $K_d$(PAR) using the model of (a) Morel et al. (2007) and (b) Wang et al. (2009).
New Blended $K_d$(PAR) Conversion Algorithm

- For open ocean waters (Morel et al., 2007):

$$K_d$(PAR) = 0.0864 + 0.8 K_d(490) – 0.00137 K_d(490)^{-1}$

- For turbid coastal waters (Wang et al., 2009):

$$K_d$(PAR) = 0.8045 $K_d$(490)\(^{0.917}\)

- Proposed $K_d$(PAR) Conversion Algorithm:

$$K_{d\,\text{Comb}} = (1-W) \cdot K_{d\,\text{Clear}} (PAR) + W \cdot K_{d\,\text{Turbid}} (PAR)$$

where weight, $W$, defined as

- $W=0$, for $\rho_{WN}(670)/\rho_{WN}(490) < 0.2604$
- $W=-1.175+4.152$, for $0.2604 \leq \rho_{WN}(670)/\rho_{WN}(490) \leq 0.2604$
- $W=1$, for $\rho_{WN}(670)/\rho_{WN}(490) > 0.4821$
Comparison of Model-derived $K_d$(PAR) using the new model with SeaBASS In Situ $K_d$(PAR) measurements (unit: m$^{-1}$).
Morel-Wang Model

Atlantic

No = 2549
Avg_Ratio = 1.13243

K_d(PAR)_Model

K_d(PAR)_Measured

Pacific

No = 94
Avg_Ratio = 0.951620

K_d(PAR)_Model

K_d(PAR)_Measured

Arctic

No = 141
Avg_Ratio = 1.59012

K_d(PAR)_Model

K_d(PAR)_Measured

Mediterranean

No = 141
Avg_Ratio = 1.14922

K_d(PAR)_Model

K_d(PAR)_Measured

Antarctic

No = 50
Avg_Ratio = 1.54151

K_d(PAR)_Model

K_d(PAR)_Measured

All

No = 2975
Avg_Ratio = 1.15556

K_d(PAR)_Model

K_d(PAR)_Measured
Matchup Comparison of MODIS-Aqua $K_d$(PAR) with In Situ $K_d$(PAR) from SeaBASS and Chesapeake Bay Program Office Database using the new $K_d$(PAR) model (unit: m$^{-1}$).
Seasonal composite images of MODIS-Aqua-derived and VIIRS-derived $K_d$(PAR) for summer (June–August 2012) in the US east coastal region (unit: m$^{-1}$).
Seasonal composite images of MODIS-Aqua-derived and VIIRS-derived $K_d$(PAR) for winter (December 2012–February 2013) in the US east coastal region (unit: m$^{-1}$).
VIIRS-derived global monthly composite images of $K_d(490)$ from Wang et al. (2009). $K_d(490)$ is one of standard VIIRS ocean color products, and has been routinely produced. (http://www.star.nesdis.noaa.gov/sod/mecb/color/)
VIIRS-derived global monthly composite images of $K_d$(PAR) from the new $K_d$(PAR) model. $K_d$(PAR) is one of standard VIIRS ocean color products, and has been routinely produced (http://www.star.nesdis.noaa.gov/sod/mecb/color/).
Conclusions

- We propose a new blended $K_d$(PAR) model for both open oceans and turbid coastal waters.

- Results show that there are significant improvements in model-derived $K_d$(PAR) values using the new approach.

- Matchup comparisons between MODIS-derived and in situ-measured $K_d$(PAR) data for the global ocean show a good agreement.

- Synoptic maps of MODIS-Aqua-derived and VIIRS-derived $K_d$(PAR) data are generated using the new method and showed consistent results with those from the previous studies.

- Our results show that satellite-derived $K_d$(PAR) data using the new $K_d$(PAR) model can provide more accurate $K_d$(PAR) data to science communities, in particular, as an important for ocean-atmospheric circulation, biogeochemical, and ecosystem models.

- $K_d$(PAR) is one of standard VIIRS ocean color products, and has been routinely produced in global ocean.

Thank you!