Diffuse Attenuation Coefficient of the Photosynthetically Available Radiation K_d(PAR)

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ABSTRACT

Satellite-based observations of diffuse attenuation coefficient for the downwelling spectral irradiance at the wavelength of 490 nm, K_d(490), and the diffuse attenuation coefficient for the downwelling photosynthetically available radiation (PAR), K_d(PAR), in the ocean can play important roles for ocean-atmospheric circulation model, biogeochemical model, and ecosystem models. Since existing K_d(PAR) models for the satellite ocean color data have wide regional variations, we need to improve K_d(PAR) model for the global ocean applications. In this presentation, we propose a new blended K_d(PAR) model from satellite measurements.

The new method has been assessed using in situ optical measurements from the NASA SeaBASS database, and is applied to the MODIS and VIIRS to derive K_d(PAR) products and compared with in situ measurements. Results show that there are significant improvements in model-derived K_d(PAR) values using the new approach, compared to those from some existing K_d(PAR) algorithm. In addition, 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- and VIIRS-derived K_d(PAR) data generated using the new method provide very similar and consistent spatial patterns in the US east coastal region. Monthly maps of VIIRS-derived K_d(PAR) data for the global ocean are also generated using the new K_d(PAR) model, and provide spatial and temporal K_d(PAR) distributions, showing consistent results with those from the previous studies. Thus, our results show that satellite-derived K_d(PAR) data can be used as an important input for ocean-atmospheric circulation, biogeochemical, and ecosystem models.

IN-SITU DATA

- 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://wwww.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 (NOAA-MSL12) ocean color data processing system has been used for processing satellite ocean color data from Level-1B to Level-2.
- MODIS-Aqua ocean color products were generated using NOAA-OCDAPS with the NIR-SWIR combined atmospheric correction algorithm (*Wang & Shi*, 2007). MODIS-Aqua Level-1B data were obtained from NASA MODAPS Service website (http://modaps.nascom.nasa.gov).
- Matchups of MODIS and *in situ* K_d(PAR) data were derived using pixels with a 5×5 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.

PROPOSED K_d(PAR) CONVERSION METHOD

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

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

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

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

- Proposed Kd(PAR) Conversion Algorithm:

$$K_d^{Comb} = (1-W)\cdot K_d^{Clear}(PAR) + W \cdot K_d^{Turbid}(PAR)$$

with weight W defined as :

W = 0,	for $\rho_{wN}(670)/\rho_{wN}(490) < 0.2604$
W = 1.175 + 4.152 × $\rho_{wN}(670)/\rho_{wN}(490)$,	for $0.2604 < \rho_{wN}(670)/\rho_{wN}(490) < 0.4821$
W = 1,	for $\rho_{wN}(670)/\rho_{wN}(490) > 0.4821$

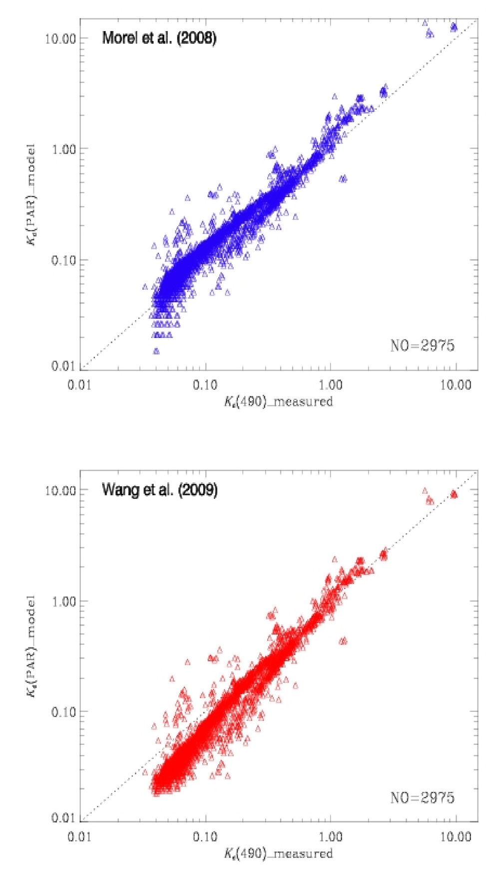

Fig. 1. Scatterplots of the model-derived K_d(PAR) versus the SeaBASS *in situ* K_d(PAR) measurements from the model of (a) *Morel et al.* (2007) and (b) *Wang et al.* (2009).

- K_d(PAR) data derived using *Morel et al.* (2007) are well matched to the *in situ* measurements in low K_d(PAR) values, but overestimated in higher K_d(PAR) values.
- On the other hand, the model-derived K_d(PAR) values using *Wang et al.* (2009) correspond reasonably well to the higher K_d(PAR) values, while the K_d(PAR) values are underestimated considerably in the lower values.

MODEL VALIDATIONS and EVALUATIONS

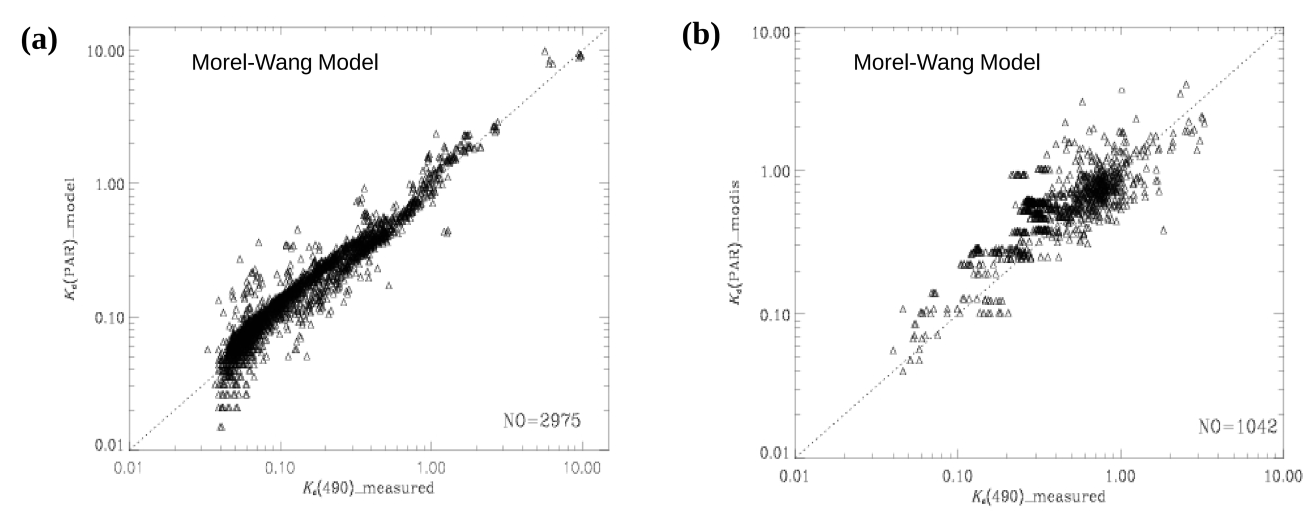

Fig. 2. (a) Comparison between the model-derived K_d(PAR) (with *in situ* $nL_w(\lambda)$) and *in situ*-measured K_d(PAR) data. (b) Matchup comparison between MODIS-derived and *in situ*-measured K_d(PAR) from SeaBASS and Chesapeake Bay Program Water Quality Database.

- K_d(PAR) data derived from the combined model correspond reasonably well to the *in situ* K_d(PAR) measurements in all ranges of K_d(PAR) values (Fig. 2a).
- MODIS-derived K_d(PAR) data using the new method are well matched to the *in situ* K_d(PAR) measurements (Fig. 2b).

K_d(PAR) IMAGES from MODIS and VIIRS

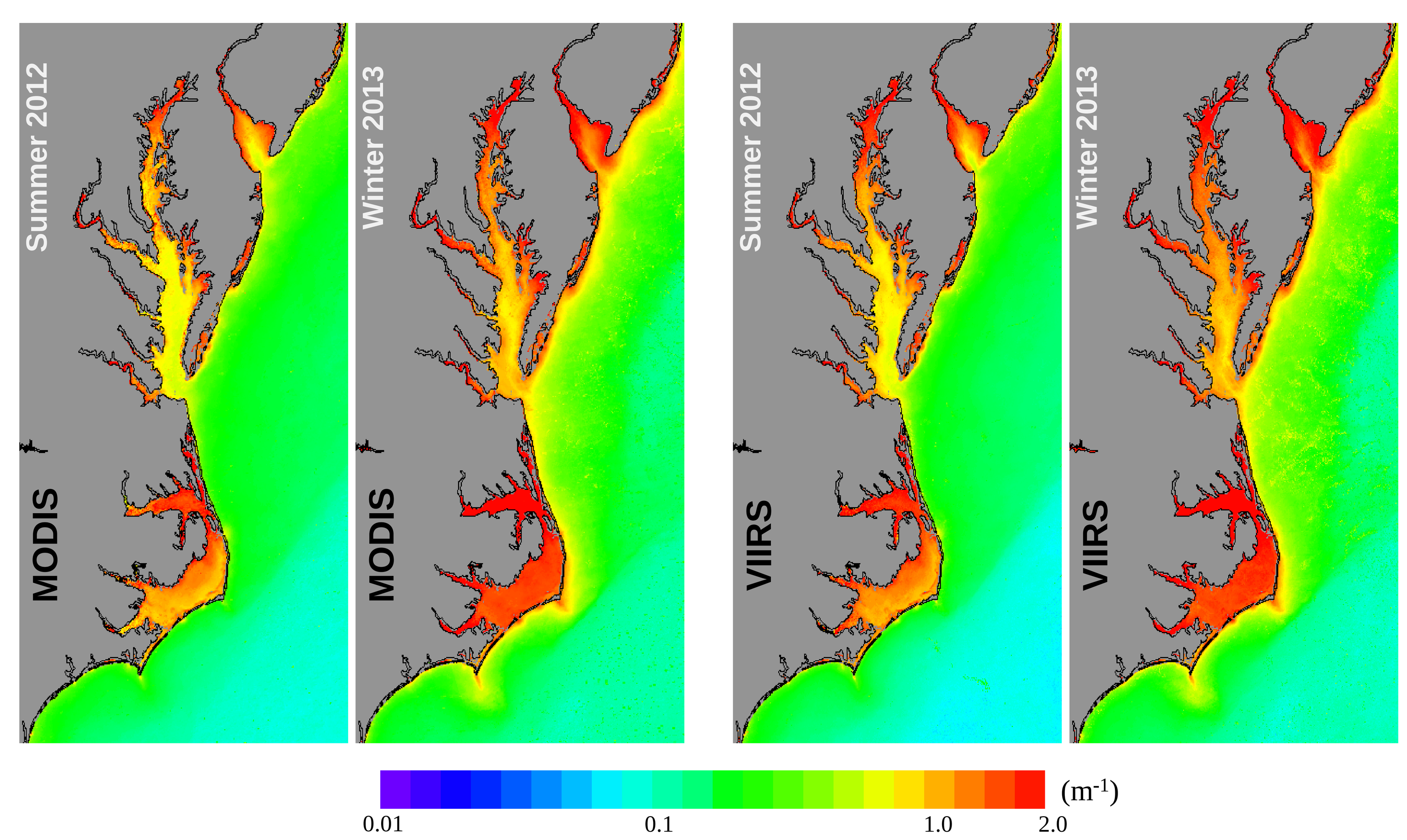

Fig. 3. Seasonal composite images of MODIS-Aqua-derived and VIIRS-derived K_d(PAR) for summer (June -August 2012) and winter (December 2012-February 2013) using the new K_d(PAR) model.

- Both MODIS-Aqua- and VIIRS-derived K_d(PAR) images have similar spatial patterns, showing high K_d(PAR) values in the turbid coastal waters while low K_d(PAR) values appeared in the clear open ocean.
- K_d(PAR) values from MODIS and VIIRS are also very similar overall although VIIRS K_d(PAR) values are slightly higher in the turbid coastal waters possibly due to the use of the NIR atmospheric correction algorithm and some issues in VIIRS SDR and ocean color EDR data.

VIIRS GLOBAL K_d(490) and K_d(PAR) IMAGES

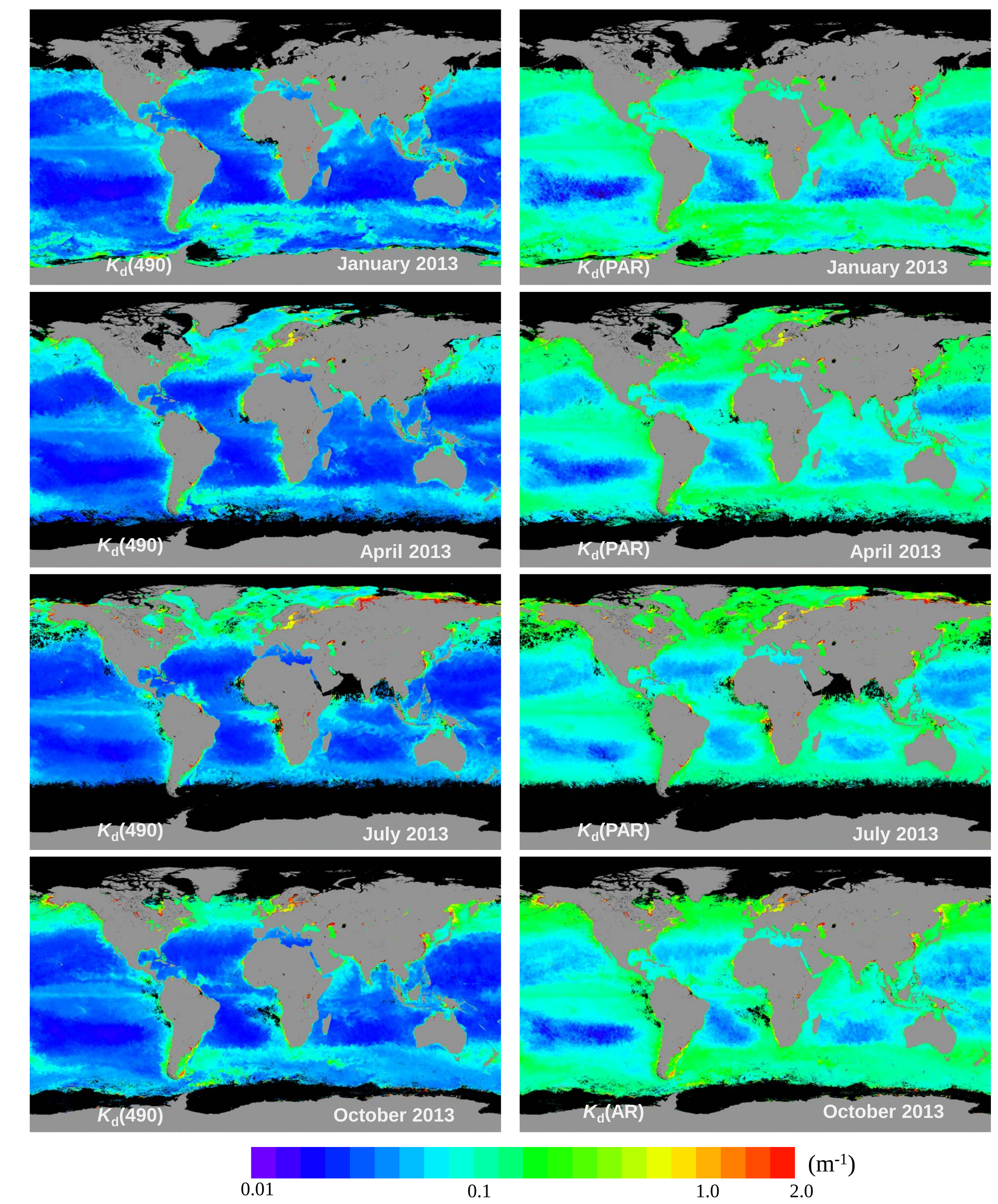

Fig. 4. VIIRS-derived global monthly composite images of K_d(490) and the corresponding K_d(PAR) from the new K_d(PAR) model for the months in 2013.

- VIIRS-derived global K_d(490) maps are very similar to those from MODIS-Aqua using *Wang et al.* (2009).
- K_d(PAR) values are generally higher than K_d(490) in open ocean, while K_d(PAR) values are slightly lower (~20%) in turbid coastal waters.
- Both K_d(490) and K_d(PAR) monthly images from VIIRS ocean color data provide apparent seasonal changes in the spatial distributions.

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 important for ocean-atmospheric circulation, biogeochemical, and ecosystem models.

Reference:

Morel, A., Y. Huot, B. Gentili, J. Werdell, S. Hooker & B. Franz (2007), Examining the consistency of products derived from various ocean color sensors in open ocean (Case 1) waters in the perspective of a multi-sensor approach, *Remote Sens. Environ.*, 111, 69-88.

Son, S. & M. Wang, (2015), Diffuse attenuation coefficient of photosynthetically available radiation Kd(PAR) for global ocean and coastal waters, *Remote Sens. Environ.*, 159, 250-258.

Wang, M., S. Son & L.W. Harding (2009), Retrieval of diffuse attenuation coefficient in the Chesapeake Bay and turbid ocean regions for satellite ocean color applications, *J. Geophys. Res.*, 114, C10011, doi:/10.1029/2009JC005286.

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