Diffuse Attenuation and Secchi Depth Products from MODIS and VIIRS: Product of Ocean Transparency

ZhongPing Lee

University of Massachusetts Boston

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$$E_d(\lambda, z) = E_d(\lambda, 0-)e^{-K_d(\lambda)z}$$

Diffuse attenuation coefficient

Morel:

$$K_d(\lambda) = K_w(\lambda) + \alpha(\lambda)[Chl]^{\beta(\lambda)}$$

Austin&Petzold （1986）:

$$K_d(\lambda) = K_w(\lambda) + M(\lambda)[K_d(490) - K_w(490)]$$

Austin&Petzold （1981）：

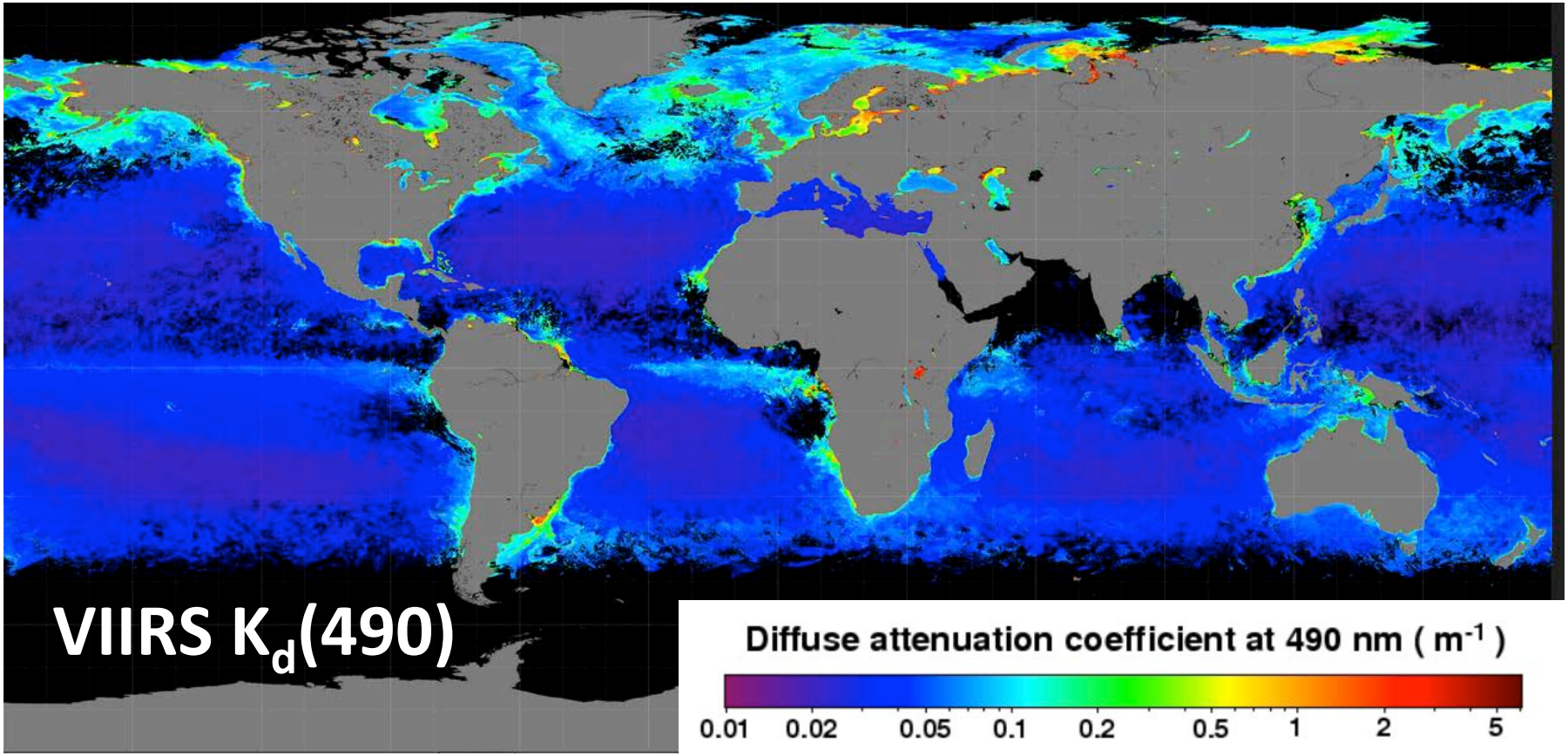
$$K_d(490) = A\left(\frac{L_w(490)}{L_w(555)}\right)^B$$

$$K_d(490) = Fun\left(\frac{R_{rs}(490)}{R_{rs}(555)}\right)$$

$$\log_{10}(K_{bio}(490)) = a_0 + \sum_{i=1}^{4} a_i \log_{10}\left(\frac{R_{rs}(\lambda_{\text{blue}})}{R_{rs}(\lambda_{\text{green}})}\right)$$

$$Kd\_490 = K_{bio}(490) + 0.0166$$

$Rrs(\lambda_{blue}) = Rrs(486)$

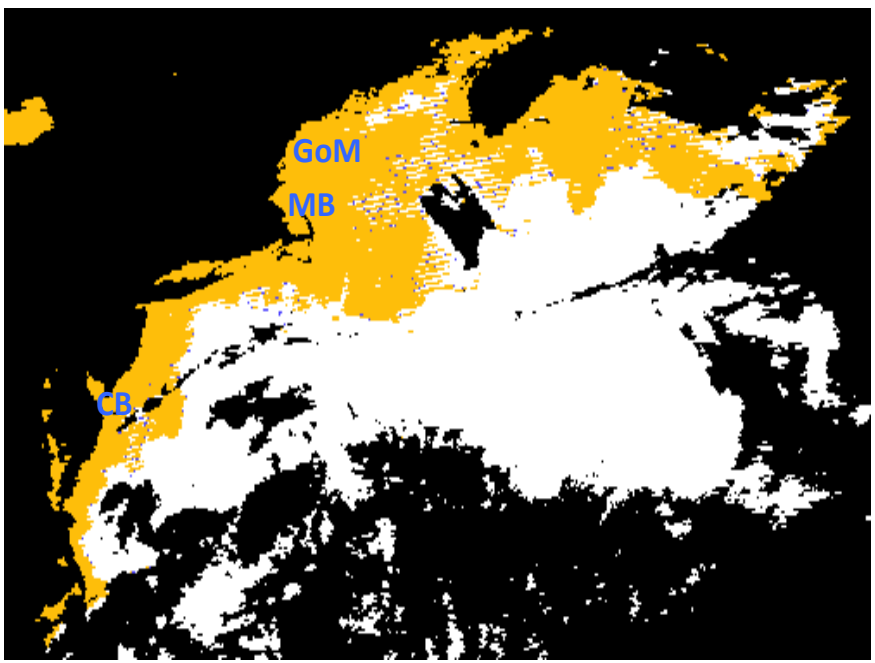

VIIRS $K_d(490)$
Diffuse attenuation coefficient at 490 nm (m^{-1})
0.01
0.02
0.05
0.1
0.2
0.5
1
2
5

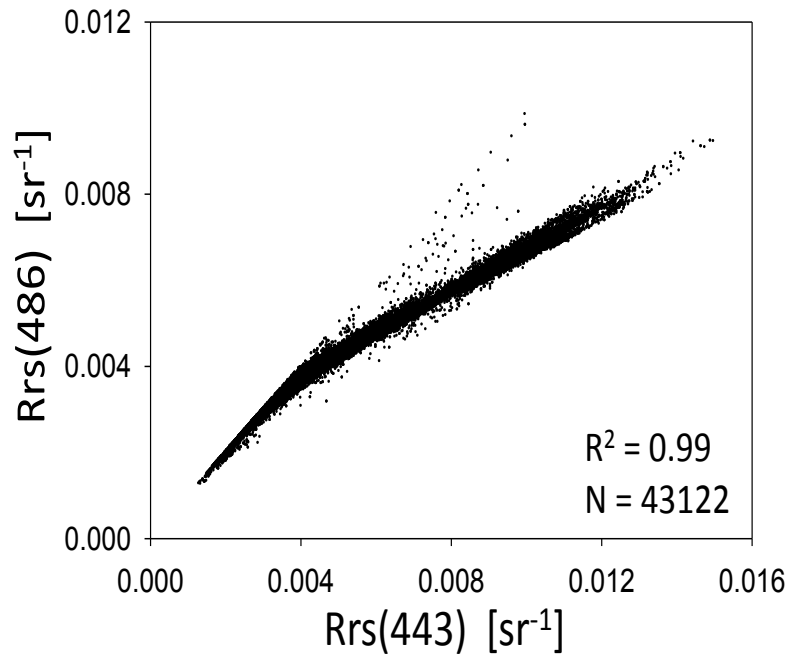
$$\log_{10}(K_{bio}(490)) = a_0 + \sum_{i=1}^{4} a_i \log_{10}\left(\frac{R_{rs}(\lambda_{\text{blue}})}{R_{rs}(\lambda_{\text{green}})}\right)$$

$$Kd\_490 = K_{bio}(490) + 0.0166$$

$$log_{10}(chlor\_a) = a_0 + \sum_{i=1}^{4} a_i log_{10}\left(\frac{R_{rs}(\lambda_{blue})}{R_{rs}(\lambda_{green})}\right)^i$$

$Rrs(\lambda_{blue})$ = Rrs(443)>Rrs(486)





The standard $K_d(490)$ and Chl products are 100% co-vary in coastal waters; but …

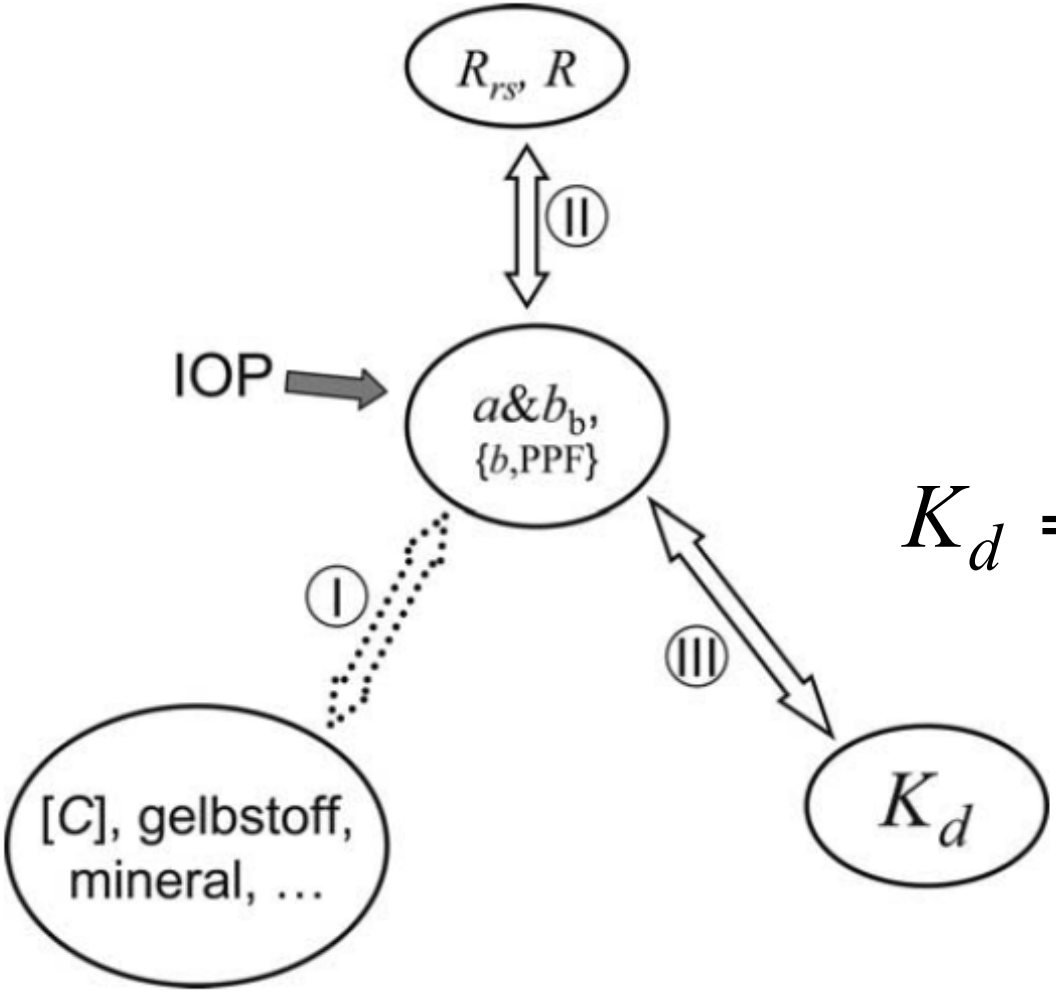
$$K_d(490) = Fun\left(\frac{R_{rs}(490)}{R_{rs}(555)}\right)$$

AOP: sun angle dependent

Nearly independent of sun angle

The two sides do not match in optical attributes.

It is imperative to generate a more consistent, and un-equivocal, ocean color K product in the 21st century



$$K_d = fun(a, b_b, \theta_w)$$

（Lee et al 2005）

Normalized diffuse attenuation coefficient (nK_d):

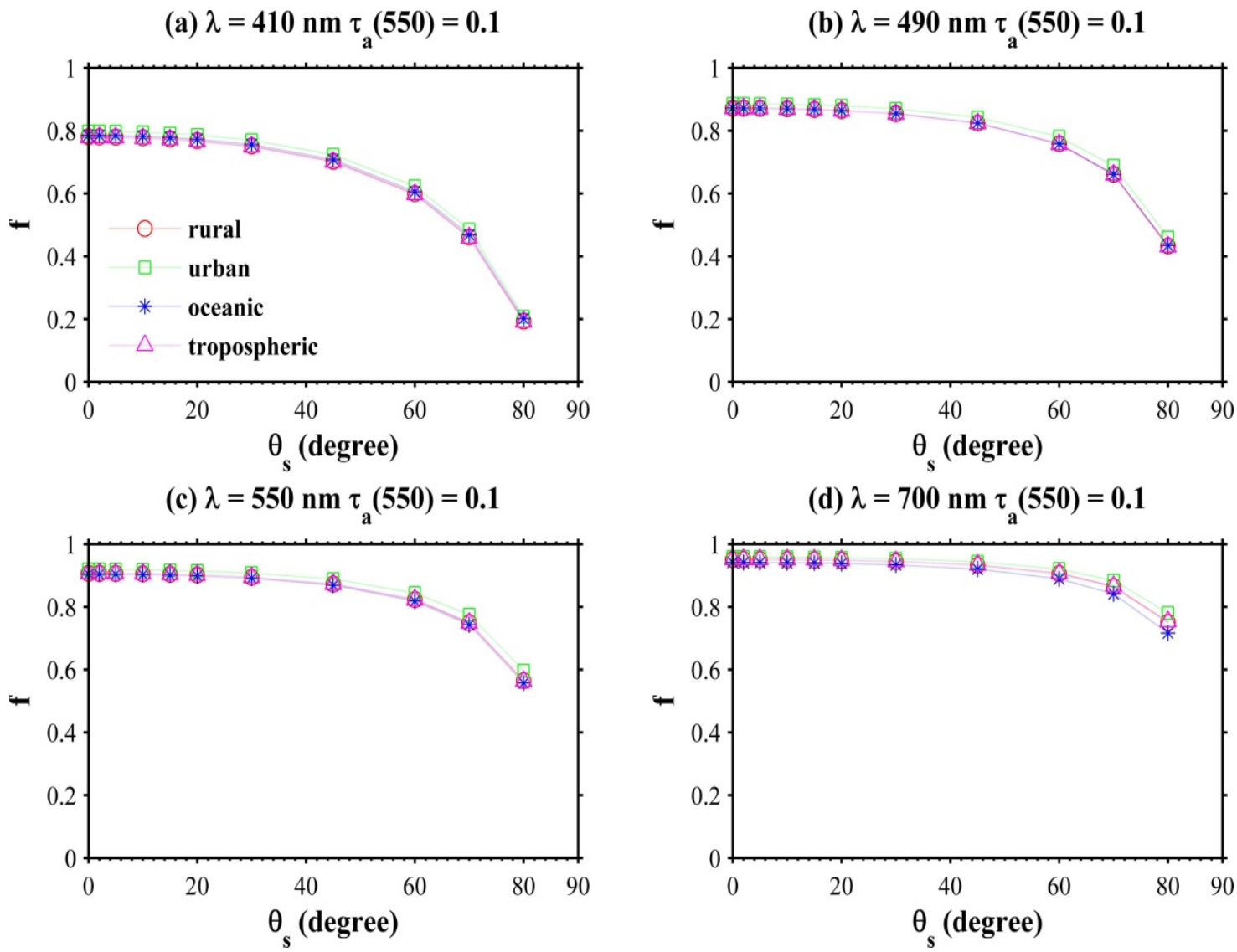
(Gordon 1989)

$$nK_d = \frac{K_d}{D_0}$$

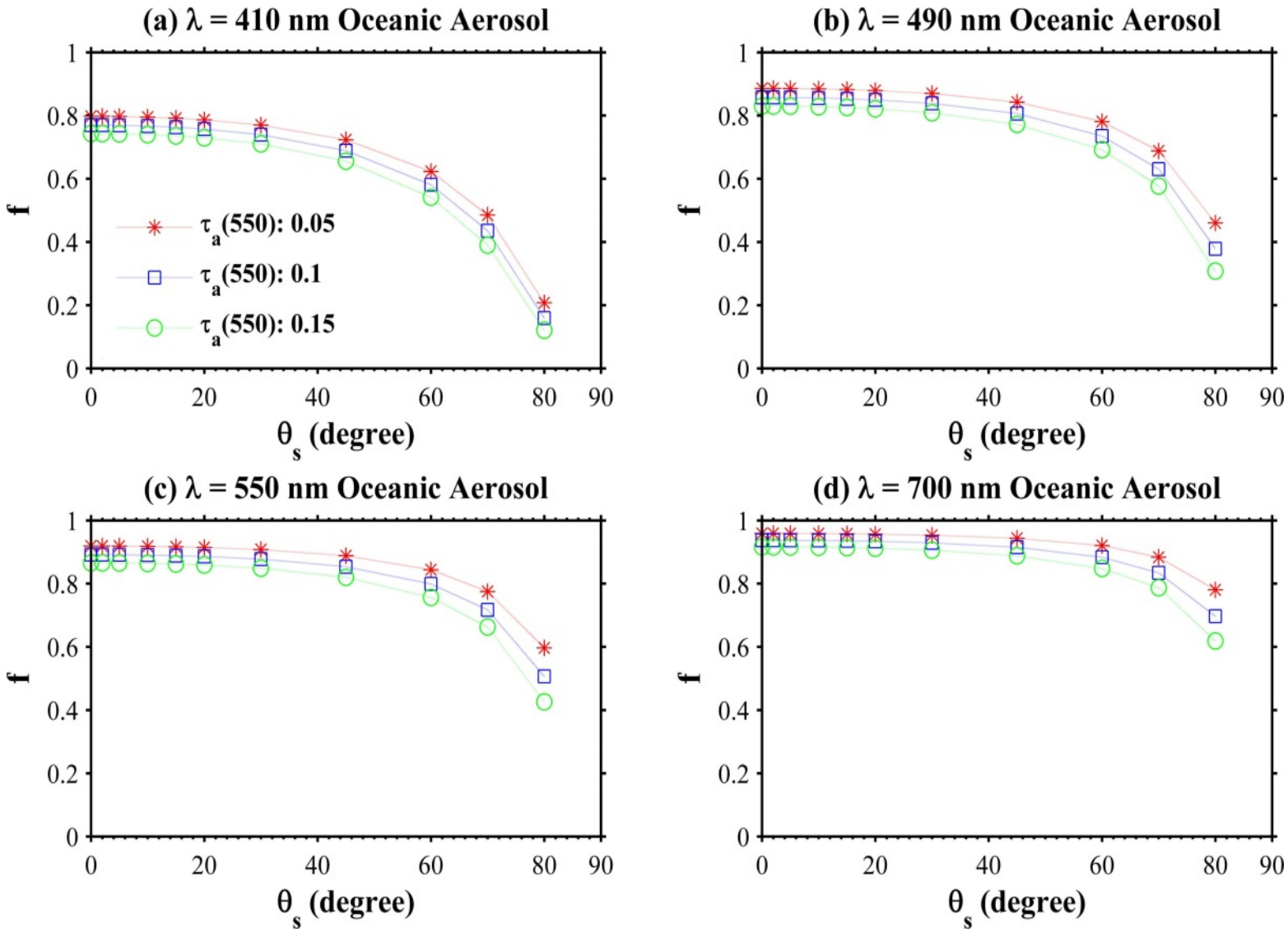
1.2

$$D_0 = \frac{f}{\cos(\theta_{sw})} + D_0(sky)(1 - f)$$

f?

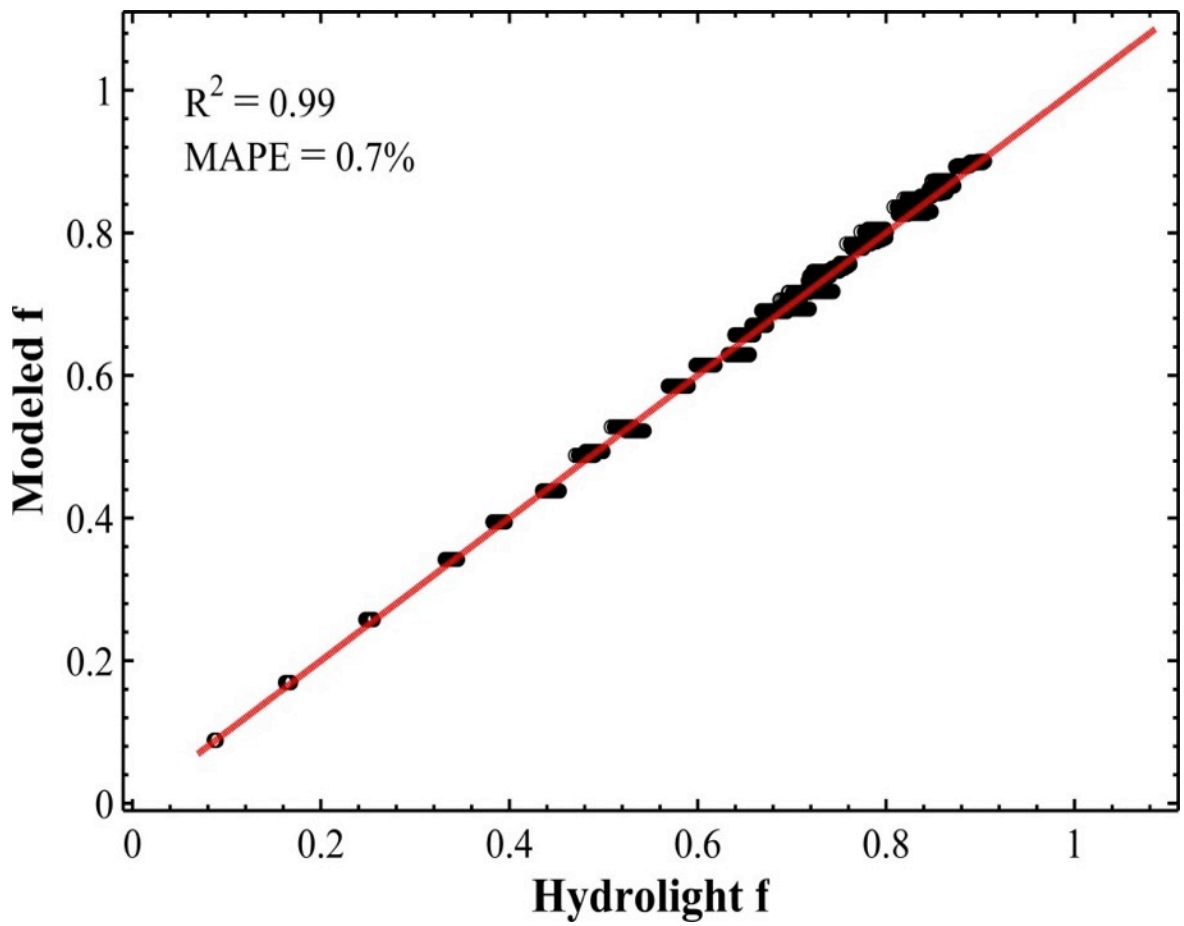


(Lin et al 2016)



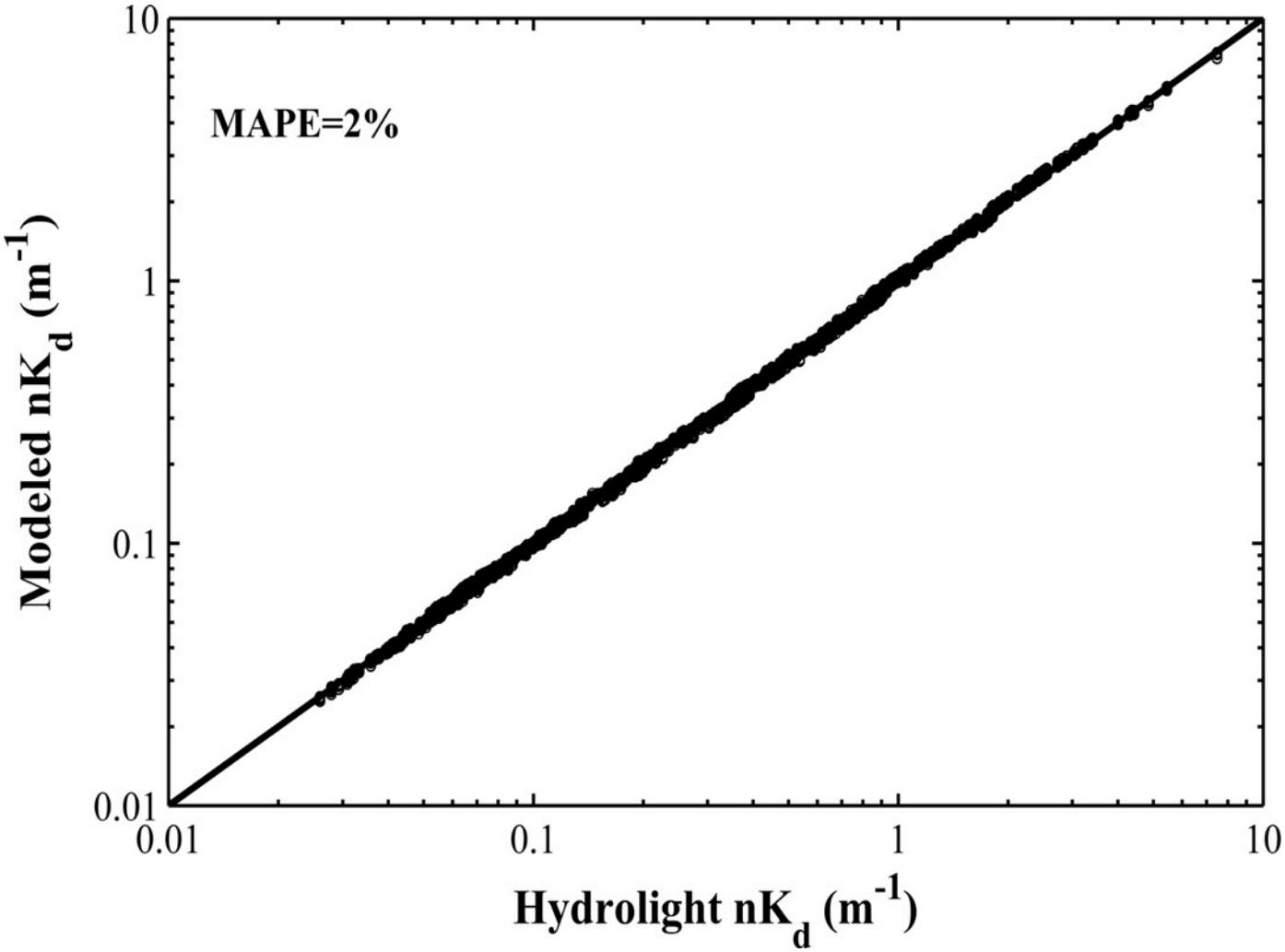
(Lin et al 2016)

$$f = m_0\left(m_1 - e^{-m_2\frac{\lambda}{\lambda_0}}\right) - \left(m_3\frac{\lambda}{\lambda_0} + m_4\right)e^{m_5\frac{\theta_s}{\theta_{s0}}}$$



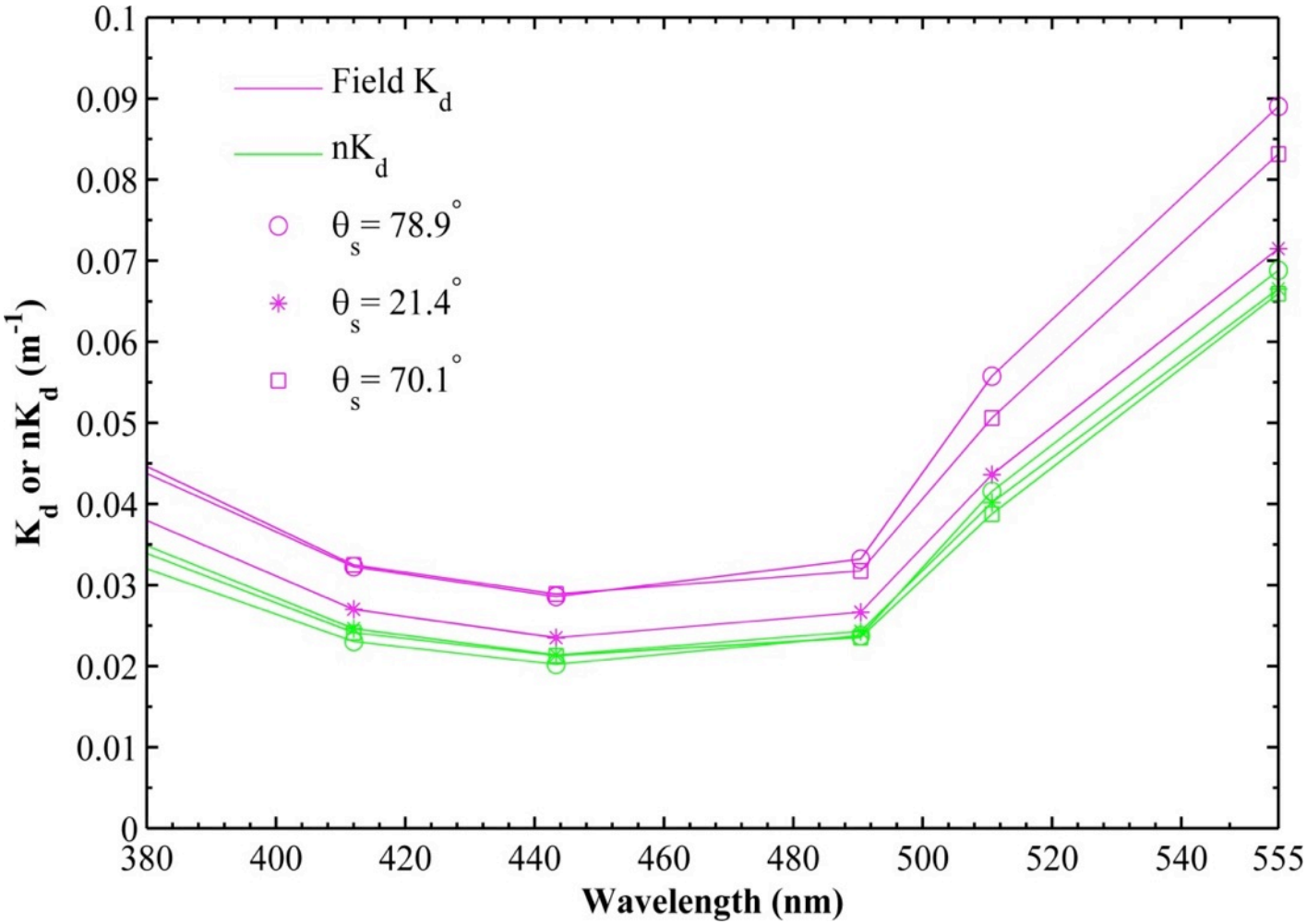
(Lin et al 2016)

$$nK_d = fun(a, b_b)$$



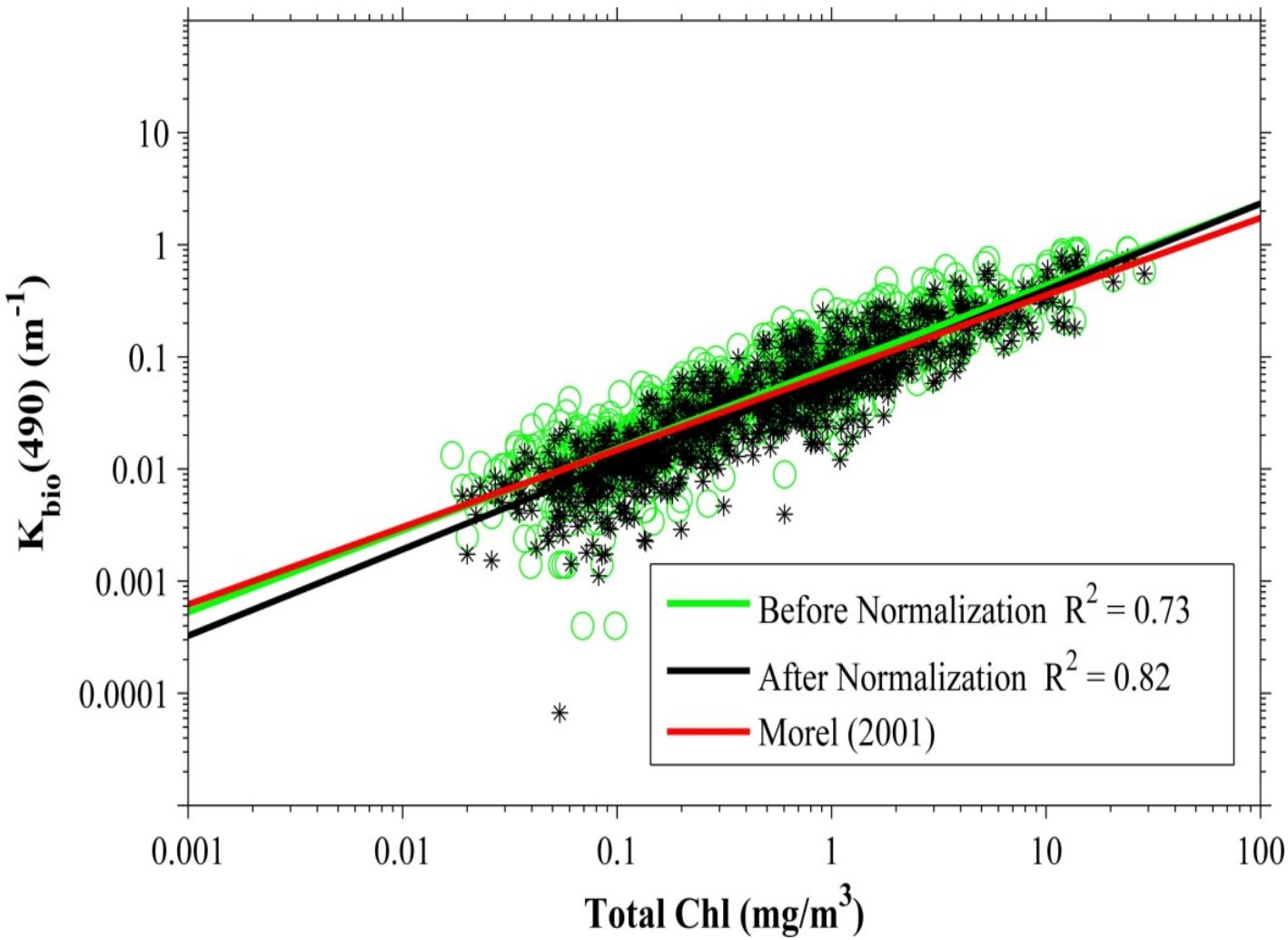
(Lin et al 2016)

K_d&D_0 ➡ nK_d



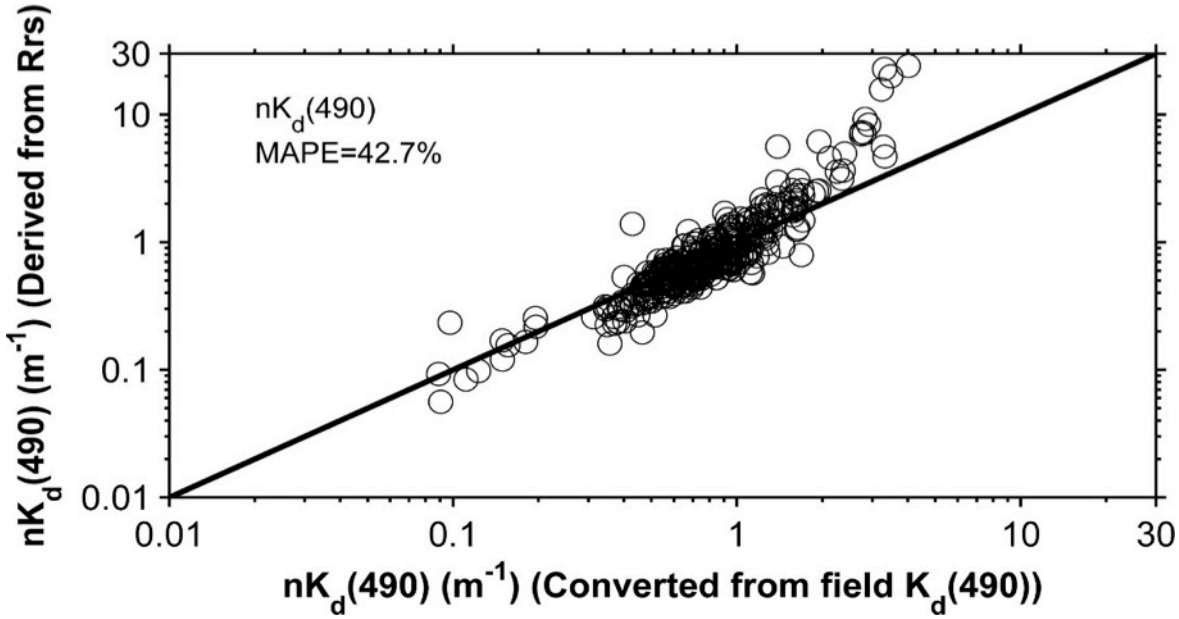
(Lin et al 2016)

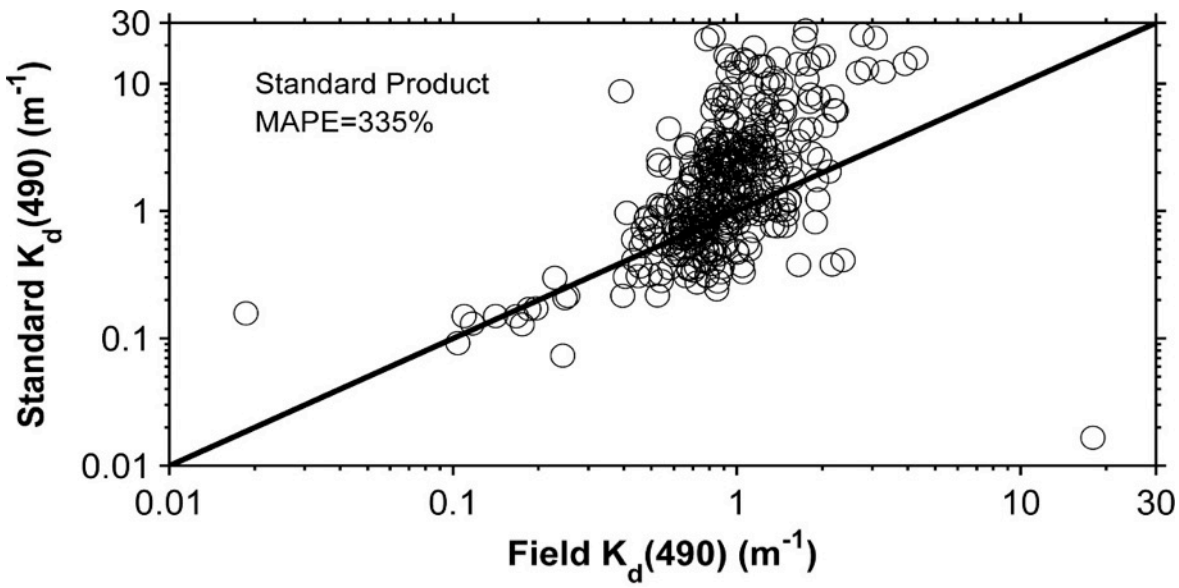
K vs Chl:



(Lin et al 2016)

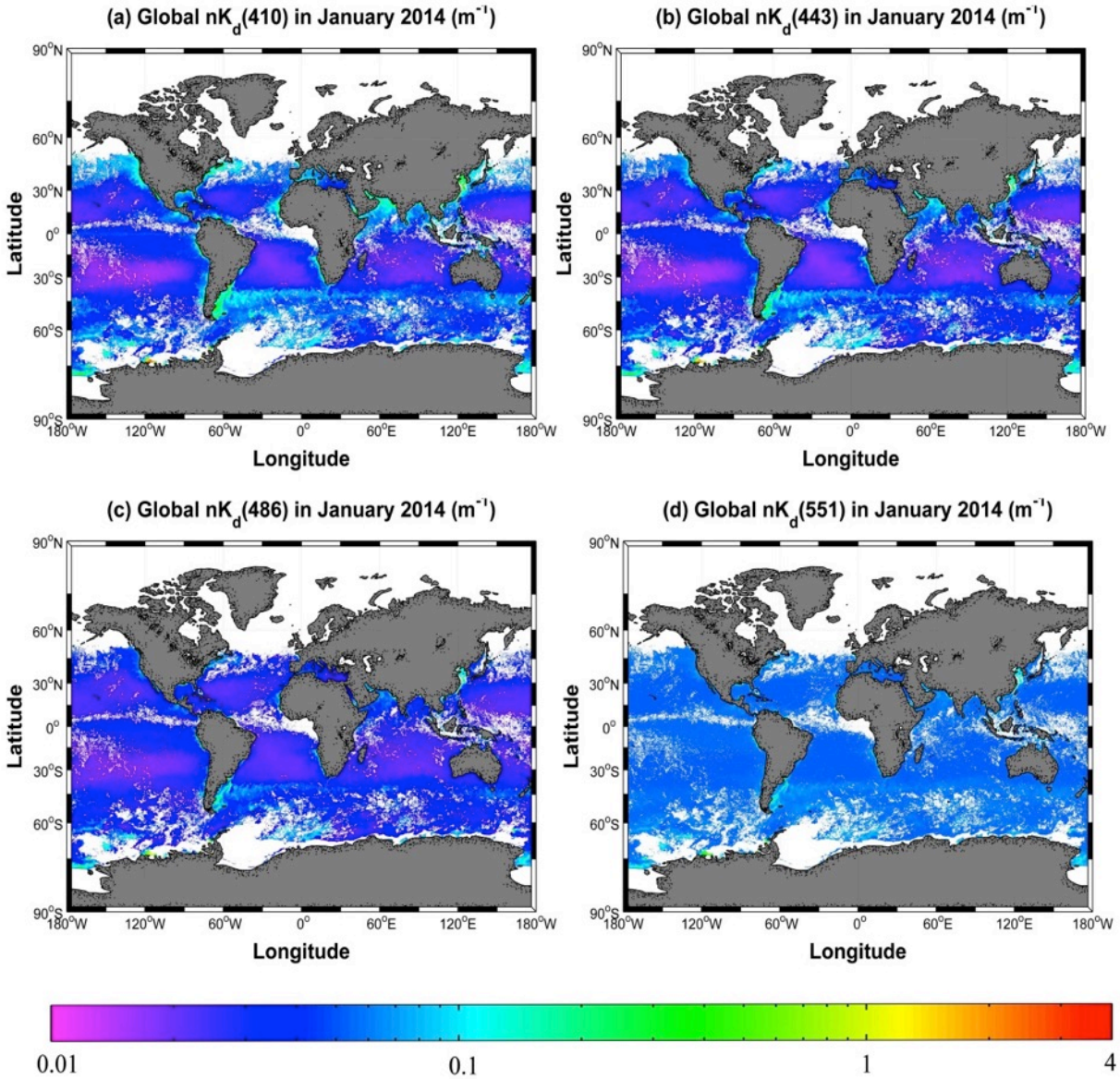
Remote Sensing nK_d: $R_{rs} \rightarrow a\&b_b \rightarrow nK_d$





(Lin et al 2016)

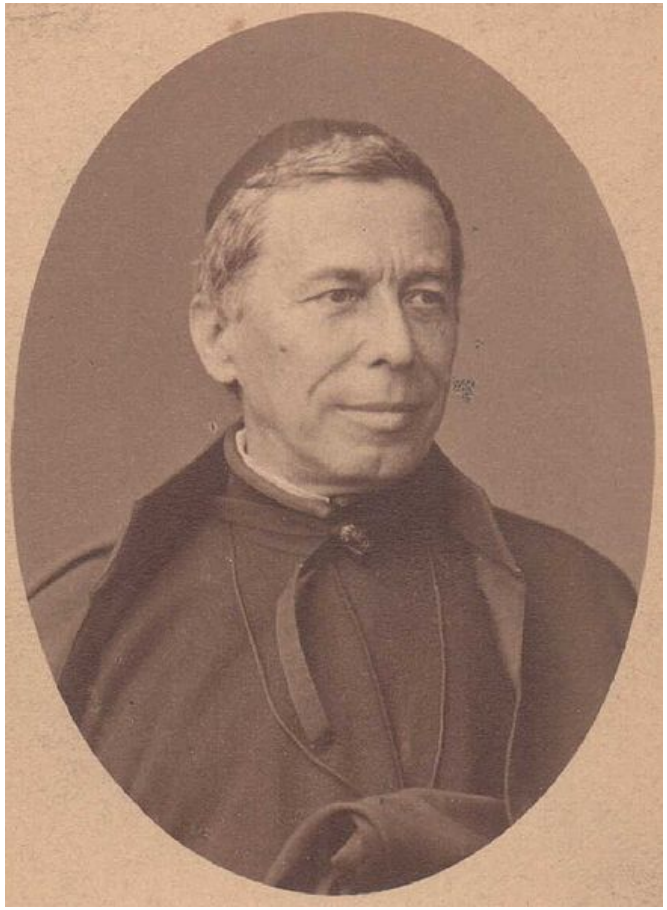
Global sample products from VIIRS:



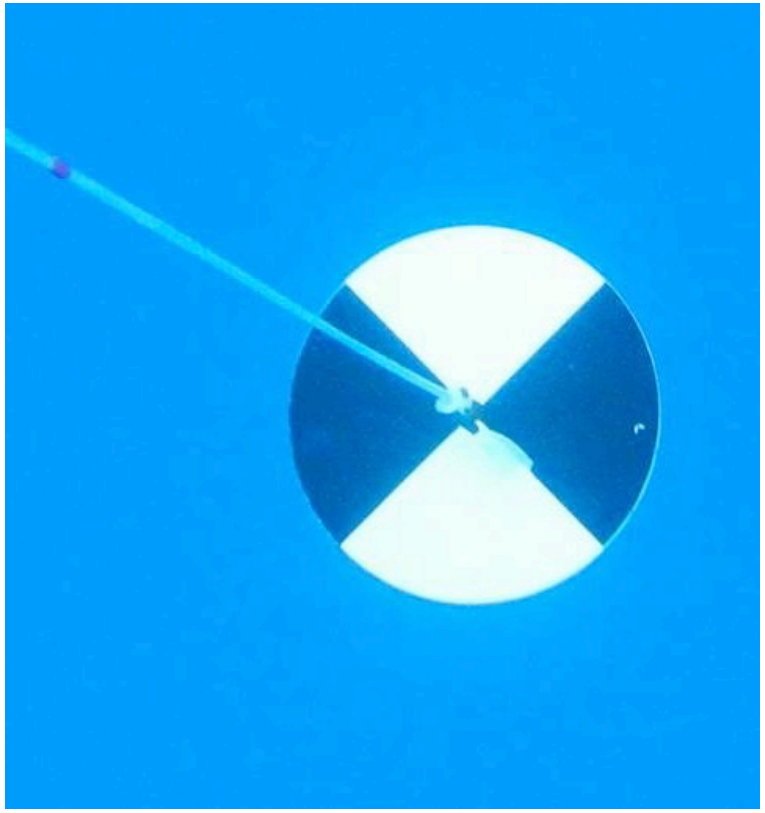
(Lin et al 2016)

Application of $nK_d(490)$???

Water clarity/transparency …



Angelo Secchi
(1818-1878)



New theoretical relationship for Z_{SD}:

$$Z_{SD} \approx \frac{1}{2.5K_d^{tr}} \ln\left(\frac{\left| r_T - r_w^{tr} \right|}{0.013} \right)$$

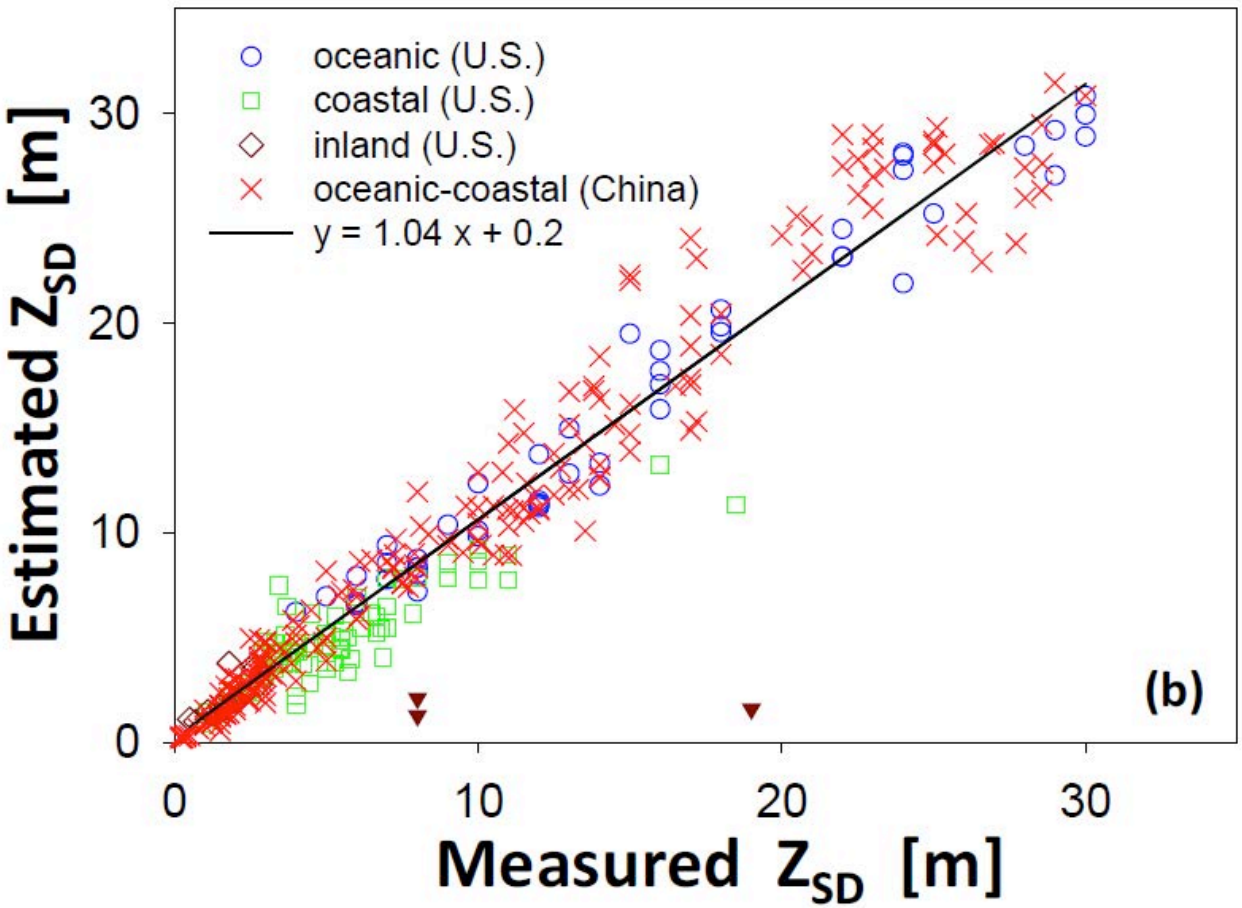
K_d^{tr} **: attenuation coefficient in the transparent window**

(Lee et al 2015)

Verification of the new Secchi disk theory

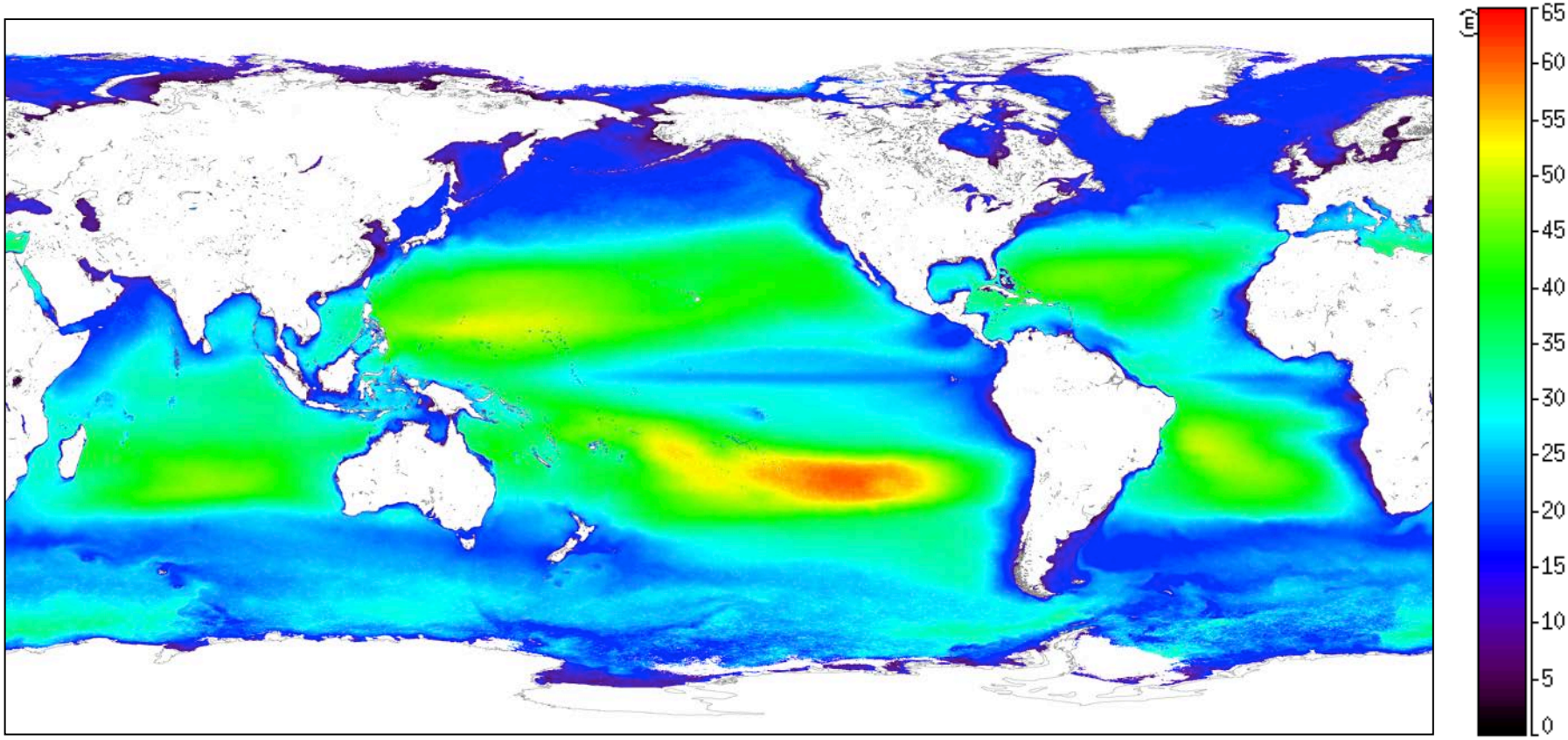
QAA （2002） Lee et al 2005

$$R_{rs} \rightarrow a\&b_b \rightarrow K_d$$



(Lee et al 2015)

Global Z_{SD}



A much more straightforward product for water clarity!

Conclusions:

1. Traditional ratio-derived $K_d(490)$ product overlooked its AOP characteristics; →

   a) the empirical $K_d(490)$ product has exactly the same spatial pattern as the Chl product in coastal region, which is not supported by ocean optics theory and observations

   b) could be an "  vs  " comparison between satellite $K_d(490)$ and insitu $K_d(490)$

2. nK_d corrects the AOP feature; →

   It is much more accurate when it is derived following a mechanistic scheme;

3. Optical properties have a spectral dependence, thus nK_d at a single wavelength has limited applications. For representation of water clarity, it is better to use Secchi depth.

It is mid 2016 now, we should have long passed the empiricism-based practices for inversion of optical properties.

Thank you!