Equations to compute the PAR at sub-surface and any depth. Santer, Dilligeard, 2001

Wavelength (nm)	Water absorption a_w (m^{-1}) Pope & Fry (1997) de 380 -> 730nm; Smith < 380 nm et > 730 nm)	Normalized (to 440 nm) no dimensional chlorophyll-specific absorption coefficient a^*_{chl} Prieur and Sathyendranath(1981)
400.000	0.007	0.687
410.000	0.005	0.828
420.000	0.005	0.913
430.000	0.005	0.973
440.000	0.006	1.000
450.000	0.009	0.944
460.000	0.010	0.917
470.000	0.011	0.870
480.000	0.013	0.798
490.000	0.015	0.750
500.000	0.020	0.668
510.000	0.033	0.618
520.000	0.041	0.528
530.000	0.043	0.474
540.000	0.047	0.416
550.000	0.057	0.357
560.000	0.062	0.294
570.000	0.070	0.276
580.000	0.090	0.291
590.000	0.135	0.282
600.000	0.222	0.236
610.000	0.264	0.252
620.000	0.276	0.276
630.000	0.292	0.317
640.000	0.311	0.334
650.000	0.340	0.356
660.000	0.410	0.441
670.000	0.439	0.595
680.000	0.465	0.502
690.000	0.516	0.329
700.000	0.624	0.215

Water scattering coefficient (m^{-1}) (Morel, 1974)

$$b_w(l) = 0.00288 \cdot \left(\frac{500}{l} \right)^{4.3}$$

particulate absorption coefficient(m^{-1}) Morel (1991)

$$a_p(l, c_{chl}) = \left(a_w(l) + 0.06 \cdot a^*_{chl}(l) \cdot c_{chl}{}^{0.65} \right) \cdot \left(1 + 0.2 \cdot \exp(-0.014(l - 440))\right) - a_w(l)$$

particulate scattering coefficient(m^{-1}) Loisel-Morel model 1998

$$b_p(l, c_{chl}) = \left(\frac{660}{l}\right) \cdot 0.407 \cdot c_{chl}^{\ 0.795}$$

Total absorption coefficient

$$a(l, c_{chl}) = a_w(l) + a_p(l, c_{chl})$$

Total backscattering coeffcient

$$b_b(l, c_{chl}) = 0.5 \cdot b_w(l) + 0.005 \cdot b_p(l, c_{chl})$$

Gaussian profile

Background biomass (mg/m3) : c_{chl}^0
Total biomass (mg/m2) : m_t
Scale parameter for width of peak (m) : s
Depth of chlorophyll maximum (m) : $z_{\max}$

$$c_{chl}(z) = c_{chl}^0 + m_t \cdot \frac{1}{s.\sqrt{2p}} \cdot \exp\left(-\frac{1}{2} \cdot \left(\frac{z - z_{\max}}{s}\right)^2\right)$$

Fresnel coefficient

$$r_{//}(w, \tilde{n}) = \frac{\sqrt{\tilde{n}^2 - \sin^2 w} - \tilde{n}\cos w}{\sqrt{\tilde{n}^2 - \sin^2 w} + \tilde{n}\cos w} \text{ et } r_{\perp}(w, \tilde{n}) = \frac{\sqrt{\tilde{n}^2 - \sin^2 w} - \cos w}{\sqrt{\tilde{n}^2 - \sin^2 w} + \cos w}$$

$$t_{//}(w, \tilde{n}) = \frac{1 - r_{//}(w, \tilde{n})}{\tilde{n}} \text{ et } t_{\perp}(w, \tilde{n}) = 1 - r_{\perp}(w, \tilde{n})$$

transmission : $t(w, \tilde{n}) = \frac{\sqrt{\tilde{n}^2 - \sin^2 w}}{2\cos w}\left(t_{//}^2(w) + t_{\perp}^2(w)\right)$

w angle d'incidence, $\tilde{n} = 1.34$

$m_s^w = \cos(w_w)$ avec $\sin w = n \sin w_w$