THE PHOTOBIOLOGICAL REGIME AND OCEANIC PRIMARY PRODUCTION

EL RÉGIMEN FOTOBIOLÓGICO Y LA PRODUCCIÓN OCEÁNICA PRIMARIA

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Photosynthetic primary production is dependent on the amount of electromagnetic radiation reaching phototrophic organisms [1]. Ultraviolet radiation (UVR) in most of the cases inhibits photosynthesis, while visible (400-700nm) and some part of infrared radiations are useful. Therefore, the latter are often called photosynthetically active radiation (PAR) [2]. The balance of UVR and PAR incident on a phytoplankton cell, combined with the ability of the species to protect from UVR and use PAR will determine the actual photosynthetic rates and consequently most of the primary production in ocean basins.

Therefore, environmental changes modifying radiation transfer in atmosphere and hydrosphere will impact ocean primary production. To account for this and other modifications of radiation transfer in terrestrial like planets, we calculate the photosynthesis rates and thus estimate variations in primary productivity.

In order to analyze the transport of radiation in the ocean, we considered changes of 10% in ocean transparency. Where:

- Specific K is equivalent to typical attenuation coefficients of radiation ($k(\lambda)$) of water type I and III as reported in Peñate *et al.* 2010 [3].
- Increased K is equivalent to these coefficients increased in 10% for PAR and UVR.
- Decreased K is equivalent to these coefficients decrease in 10% for PAR and UVR.
- Crossed K is equivalent to these coefficients decrease in 10% for UVR and increased in 10% for PAR. This case resembles the current situation with the climatic change.

We assume two solar zenith angles: 0 and 60 degrees, representing two extremes of solar irradiation. To account for the reflected light we apply Fresnel formulae to the interface air-water:

$$R_S = \left| \frac{n_a \cos\theta_i - n_w \cos\theta_t}{n_a \cos\theta_i + n_w \cos\theta_t} \right|^2 \tag{1}$$

$$R_P = \left| \frac{n_a \cos\theta_t - n_w \cos\theta_i}{n_a \cos\theta_t + n_w \cos\theta_i} \right|^2 \tag{2}$$

R_S and R_P are the reflexion coefficients for *s*- and *p*-polarized lights. For non-polarized light the reflexion coefficient R is:

$$R = \frac{R_S + R_P}{2} \tag{3}$$

Refraction angles θ_t are found using Snell's law:

$$n_a \sin\theta_i = n_w \sin\theta_t \tag{4}$$

Spectral irradiances just below the interface air-water are found through:

$$E\left(\lambda, 0^-\right) = \left[1 - R\right] E\left(\lambda, 0^+\right) \tag{5}$$

Spectral irradiances at depth z are found using Lambert-Beer's law:

$$E(\lambda, z) = E\left(\lambda, 0^-\right) \exp\left[-K(\lambda).z\right] \tag{6}$$

Total irradiances of PAR at depth z are found using:

$$E_{PAR}(z) = \sum_{400nm}^{700nm} E(\lambda, z)\Delta\lambda \tag{7}$$

Spectral irradiances of UVR are convolved with a biological action spectrum for photosynthesis inhibition $\varepsilon(\lambda)$. Then, biologically effective UV irradiances at depth z are:

$$E^*_{UV}(z) = \sum_{200nm}^{399nm} \varepsilon(\lambda) E(\lambda, z)\Delta\lambda \tag{8}$$

Photosynthesis rates at depth z are found through the so-called E model [4]:

$$\frac{P}{P_S}(z)=\frac{1-\exp\left[-E_{PAR}(z)/E_S\right]}{1+E^{*}_{UV}(z)} \tag{9}$$

Where, E_S is the characteristic irradiance for the saturation of the light.

(a)

(b)

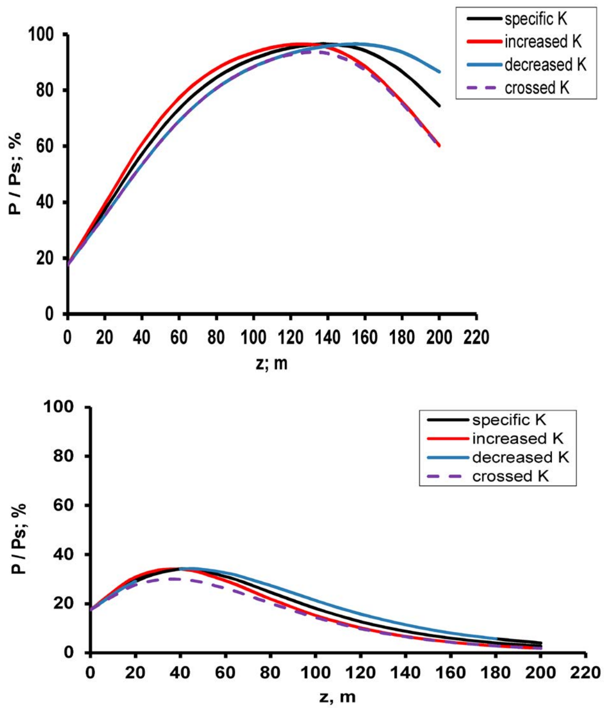

Fig. 1 Relative photosynthesis rate (%) at the photic zone, for water type I. Solar zenith angle 0 degree. (a) E_S = 2 W/m^{-2}. (a) E_S = 100 W/m^{-2}

The quantification of UVR and PAR effects in photosynthetic primary production, depending on the angle of incident of solar light, with changes of 10% in ocean transparency, is shown in Fig. 1 - 3.

(a)

(b)

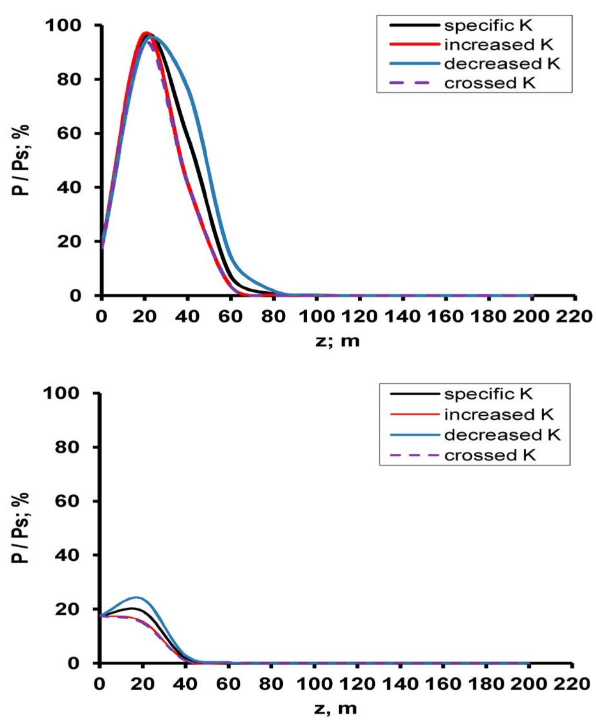

Fig. 2 Relative photosynthesis rate (%) at the photic zone, for water type III. Solar zenith angle 0 degree. (a) E_S = 2 W/m^2. (a) E_S = 100 W/m^2

(a)

(b)

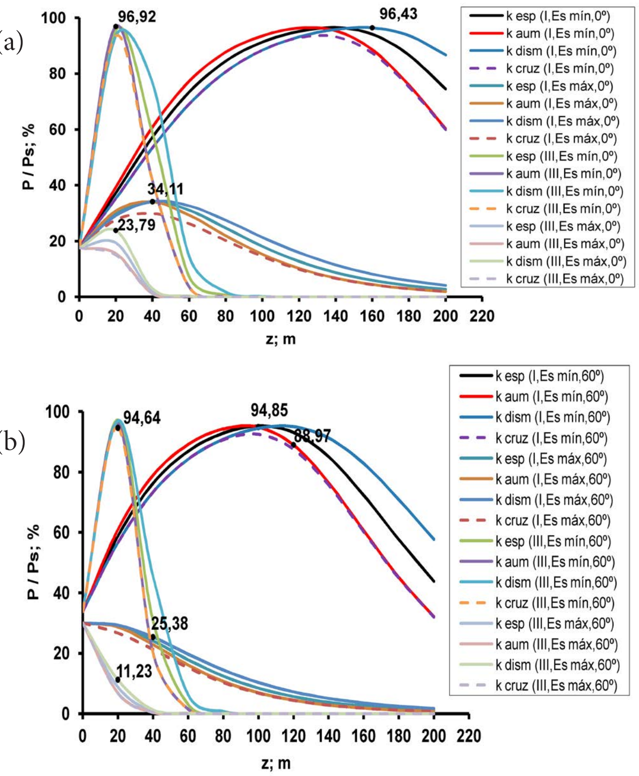

Fig. 3 Relative photosynthesis rate (%) at the photic zone (a) Solar zenith angle 0 degree. (b) Solar zenith angle 60 degree.

The absorption of UV and PAR radiations by the oceanic waters turns out to be differential for mentioned variations in ocean transparency, the optical ocean water types and the angle of incident of solar light.

The conditions where photosynthesis was less inhibited was for type water I, with organisms that have a high photosynthetic efficiency (E_S = 2 Wm^{-2}) and when solar radiation influenced with $\theta_i = 0^o$.

The greater inhibition of photosynthesis was recorded for type waters III, with organisms that have low photosynthetic efficiency (E_S =100 Wm^{-2}) and when solar radiation influenced with $\theta_i = 60^o$.

With respect to the four types of *K* that were defined, the lowest values in photosynthesis rates were observed for the crossed *K* and increased *K*. These results can be related to the alteration of global biogeochemical cycles, which alter ocean transparency. Alteration of global biogeochemical cycles in the context of current climate change seems to make the atmosphere and hydrosphere more transparent to UVR and less so to PAR.

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