Estimating Photosynthesis Parameters from a Global Database of *In Situ* Production Profiles

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Introduction

We base our analyses on a recently compiled global phytoplankton primary-production dataset by Mattei and Scardi (2021), which aggregates *in situ*, depth-resolved ^{14}C measurements from 6 084 profiles collected between 1958 and 2017. Of these, 2 214 profiles originated from the older Ocean Productivity compilation (covering up to 1994), and the remaining 3 870 were newly retrieved to expand both spatial and temporal coverage. Each profile includes not only the vertical distribution of phytoplankton production (mg C m^{-3} d^{-1}) but also corresponding chlorophyll a concentration, temperature, and photosynthetically active radiation (PAR), along with ancillary metadata (e.g., sampling date, location, bathymetry, mixed-layer depth, distance from coast). Please visit `photoclim.org` for more information on these activities and the PHOTOCLIM project.

The amount of carbon assimilated per unit biomass per unit time as a function of available irradiance is expressed with a photosynthesis–irradiance function $p^B(I)$. One of the most common forms is given by Platt et al. (1980):

$$p^B(I) = P_m^B\left(1 - \exp\left(-\frac{\alpha^B I}{P_m^B}\right)\right),$$

where α^B is the initial slope and P_m^B is the assimilation number.
Daily normalized production P_T^B at depth z is given as:

$$P_T^B(z) = P_m^B D f_z(I_*^m e^{-Kz}),$$

where B is biomass, D is daylength, and f_z is a dimensionless function:

$$f_z(I_*^m e^{-Kz}) = \sum_{n=1}^{\infty}\frac{2(I_*^m e^{-Kz})^{2n-1}(2n-1)!!}{\pi(2n-1)!(2n-1)!!} - \sum_{n=1}^{\infty}\frac{(I_*^m e^{-Kz})^{2n}(2n-1)!!}{(2n)!(2n)!!}.$$

Its argument is the dimensionless noon irradiance I_*^m multiplied by e^{-Kz}, where K is the attenuation coefficient. Similarly, daily normalized water column production is given as:

$$P_{Z,T}^B = \frac{P_m^B D}{K} f(I_*^m),$$

where the dimensionless function $f(I_*^m)$ is defined as:

$$f(I_*^m) = \sum_{n=1}^{\infty}\frac{2(I_*^m)^{2n-1}(2n-2)!!}{\pi(2n-1)(2n-1)!(2n-1)!!} - \sum_{n=1}^{\infty}\frac{(I_*^m)^{2n}(2n-1)!!}{2n(2n)!(2n)!!}.$$

Using the inverse modelling method from Kovač et al. (2016) we were able to estimate photosynthesis parameters from measured in situ production profiles.

Methods

We counted, for each profile in the Mattei & Scardi dataset, how many individual depth measurements it contains, as seen in Figure 1. Only profiles with more than 4 measurement depths were used.

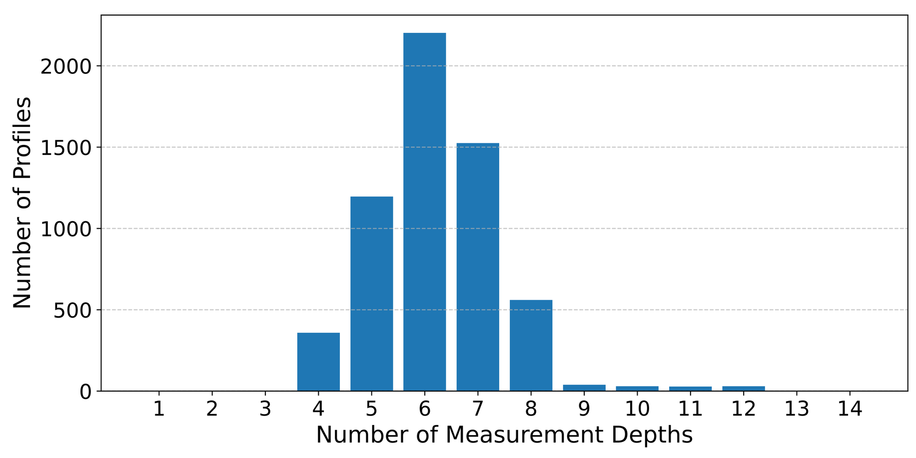

Figure 1: Profile count by number of measurement depths.

To estimate α^B and P_m^B, we applied a nonlinear least-squares fit to each depth-resolved profile in the Mattei & Scardi dataset, using the Kovač et al. (2016) function to obtain best-fit values. To compare model results, we rewrote daily normalized production as $P_T^B(z)/P_m^B D = f_z(I_*^m e^{-Kz})$, treating $I_*^m e^{-Kz}$ as the independent variable X and $P_T^B(z)/P_m^B D$ as the dependent variable Y. The same approach applies to normalized water column production, where I_*^m is X and $P_{Z,T}^B K/P_m^B D$ is Y.

Results

Values of X and Y can be calculated from measured and estimated values of all the parameters present, as seen in the Figure 2 and 3. Histograms of relative errors in Figure 4 demonstrate that the majority of error values are centered near zero, indicating strong agreement between modeled and measured estimates.

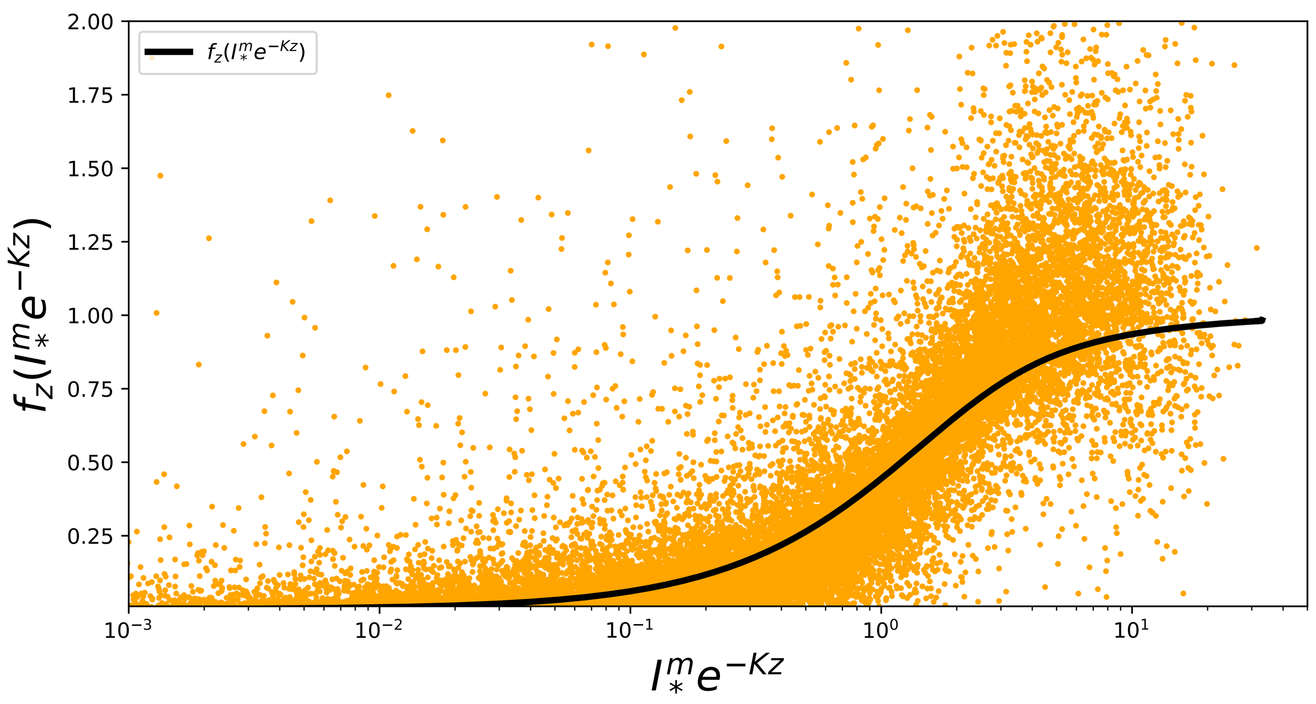

Figure 2: The comparison of model and measured normalized daily production at depth. First depth is removed because of photoinhibition.

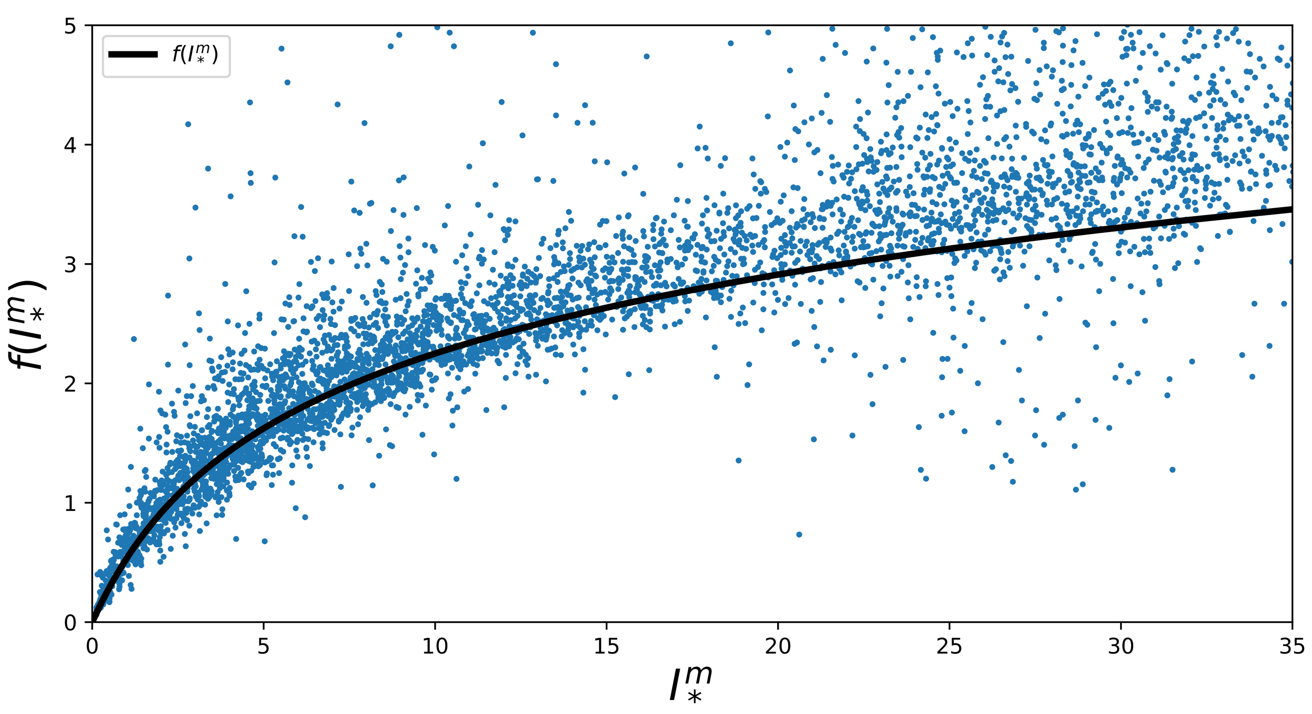

Figure 3: The comparison of model and measured normalized daily watercolumn production.

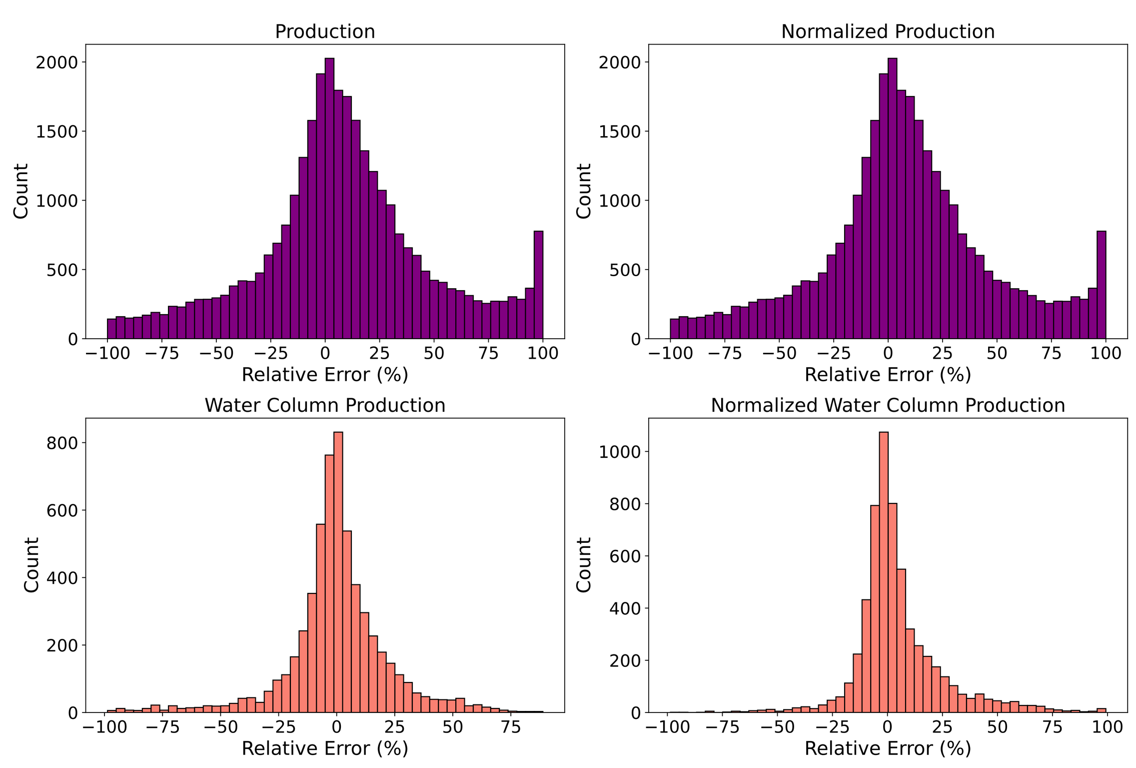

Figure 4: Relative errors for production, normalized production, water column production and normalized water column production.

References

Mattei, F., & Scardi, M. (2021). Collection and analysis of a global marine phytoplankton primary-production dataset. *Earth System Science Data*, **13**(10), 4967–4985. doi: 10.5194/essd-13-4967-2021
Platt, T., Gallegos, C. L., & Harrison, W. G. (1980). Photoinhibition of photosynthesis in natural assemblages of marine phytoplankton. *Journal of Marine Research*, **38**(4), 687–701.
Kovač, Ž., Platt, T., Sathyendranath, S., Morović, M., & Jackson, T. (2016). Recovery of photosynthesis parameters from in situ profiles of phytoplankton production. *ICES Journal of Marine Science*, **73**(1), 191–201. doi: 10.1093/icesjms/fsv204