

INTERCOMPARISON AND SENSITIVITY ASSESSMENT OF LAKE PRIMARY PRODUCTION MODELS FOR REMOTE SENSING

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INTRODUCTION

- Lakes benefit human wellbeing but are threatened by human activities.
- Trophic state and aquatic carbon cycle are key indicators of lake ecosystem health, with primary production (PP) being a priority for monitoring dynamics.
- Bio-optical models describe light availability and efficiency of algae particles to absorb and use photon energy for carbon assimilation.

MODEL OVERVIEW

Primary production can be calculated as $PP(z) = E(z, \lambda) \times Qpar(z) \times \Phi$, where the three terms are:

- $E(z, \lambda)$, the Photosynthetically Active Radiation (PAR) at depth z and wavelength λ ,
- $Qpar(z)$, the photosynthetically absorbed radiation at depth z , and
- Φ , the photosynthetic quantum yield.

MODEL DESCRIPTIONS

1. Semi-empirical model (Soomets et al. 2021):

$$PP = E(z) \times a_{phy} \times \phi, \text{ with } \phi = f(E(0), Chla) \text{ and } a_{phy} = f(Chla)$$

2. Absorption based model (Lee et al. 2011):

$$PP = \phi_m \frac{K_\phi \exp(-v \times E(z))}{K_\phi + E(z)} \times a_{phy} \times E(z), \text{ with } a_{phy} = f(Chla)$$

3. Vertically generalized production model (VGPM) (Behrenfeld et al. 1997):

$$PP = 0.66125 \times P_{opt}^B \times \frac{E(0)}{E(0) + 4.1} \times Z_{eu} \times Chla \times D_l, \text{ with } P_{opt}^B = f(SST)$$

4. Depth integrated model (DIM) (Sayers et al. 2021):

$$PP = \phi \times Chla \times E(z), \text{ with } \phi = f(lat)$$

Utilities

$$E(z) = E_0 \exp(-K_d(z) \times z) \quad K_d \approx \frac{1.44}{\text{Secchi depth}} \quad Z_{eu} \approx \text{Secchi depth} \times 2.3$$

PP = primary production (mg C h⁻¹), a_{phy} = absorption by phytoplankton, ϕ_m = maximum quantum yield, K_ϕ = half-saturation constant of quantum yield, Z_{eu} = depth of the euphotic zone, P_{opt}^B = maximum photosynthetic rate, SST = sea surface temperature, K_d = attenuation coefficient

Table 1. Primary production models

MODEL APPLICATION

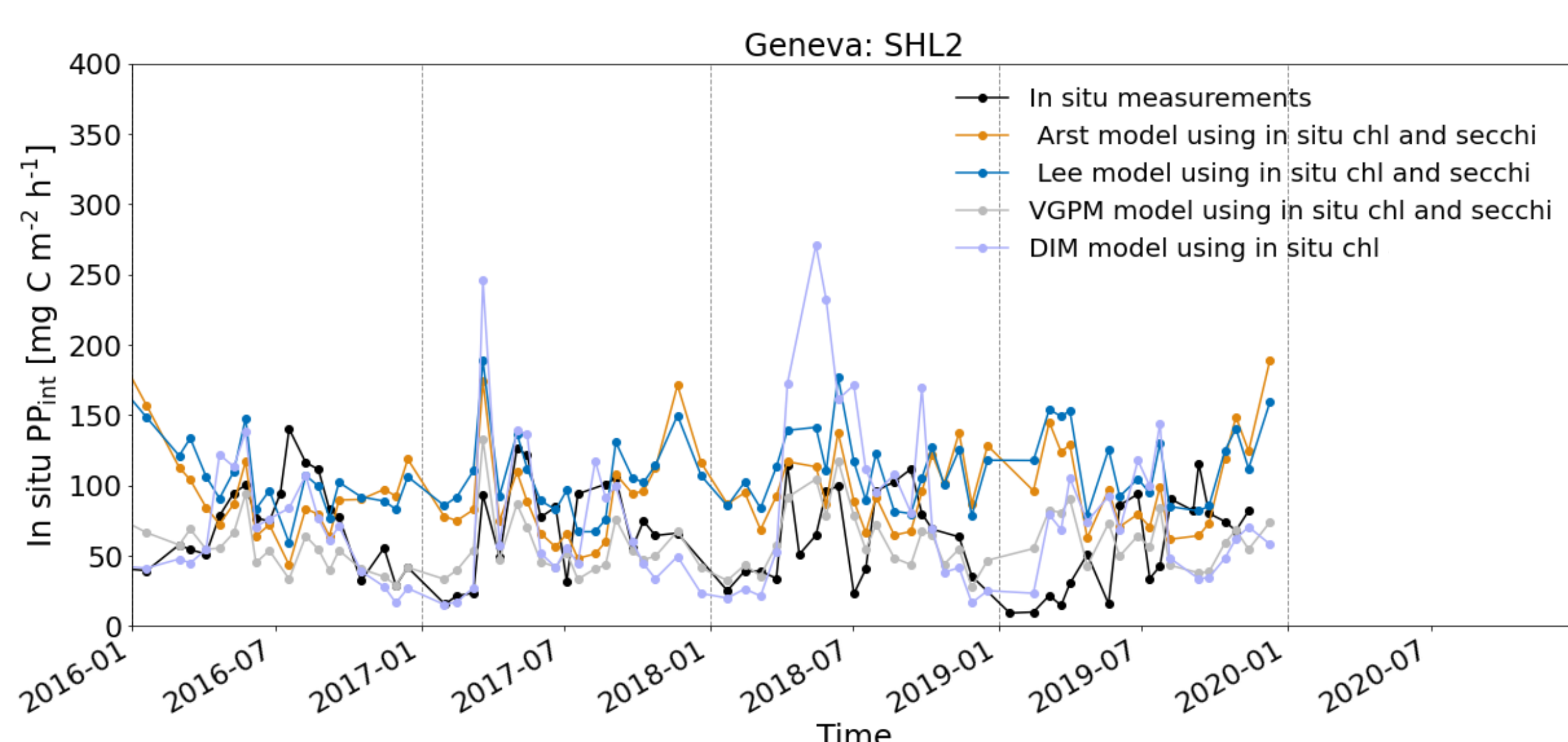


Figure 1. Primary production models compared to measurements in Lake Geneva.

- The four different models (Arst's model, Lee's model, VGPM, and DIM) were applied to chlorophyll a, and Secchi depth data and compared to primary production data, which were measured in Lake Geneva (at a sampling point called SHL2).
- The data was collected by CIPEL between 2016 and 2020.
- The results are not satisfactory yet as the models did not capture the variability of the measured primary production.

MODEL PERFORMANCE

- Primary production model performance was compared using the root mean square difference (RMSD) to quantify the error between in-situ measured and modelled PP.

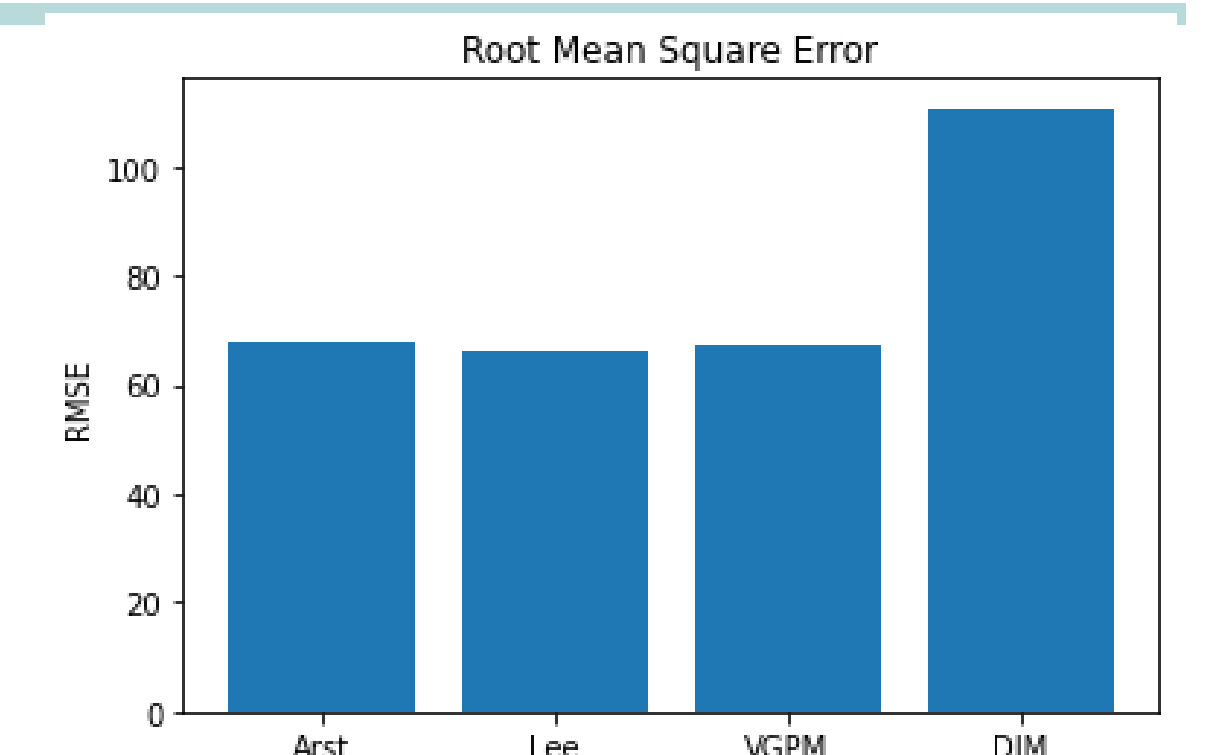


Figure 2. Root mean square error of primary production models.

SENSITIVITY ANALYSIS

- Sensitivity analysis can be performed using the python library SALib (Herman and Usher, 2017)
- Total order indices (ST) consider the influence of parameters and their interactions on the output, whereas first order indices (S1) only consider the influence of parameters.

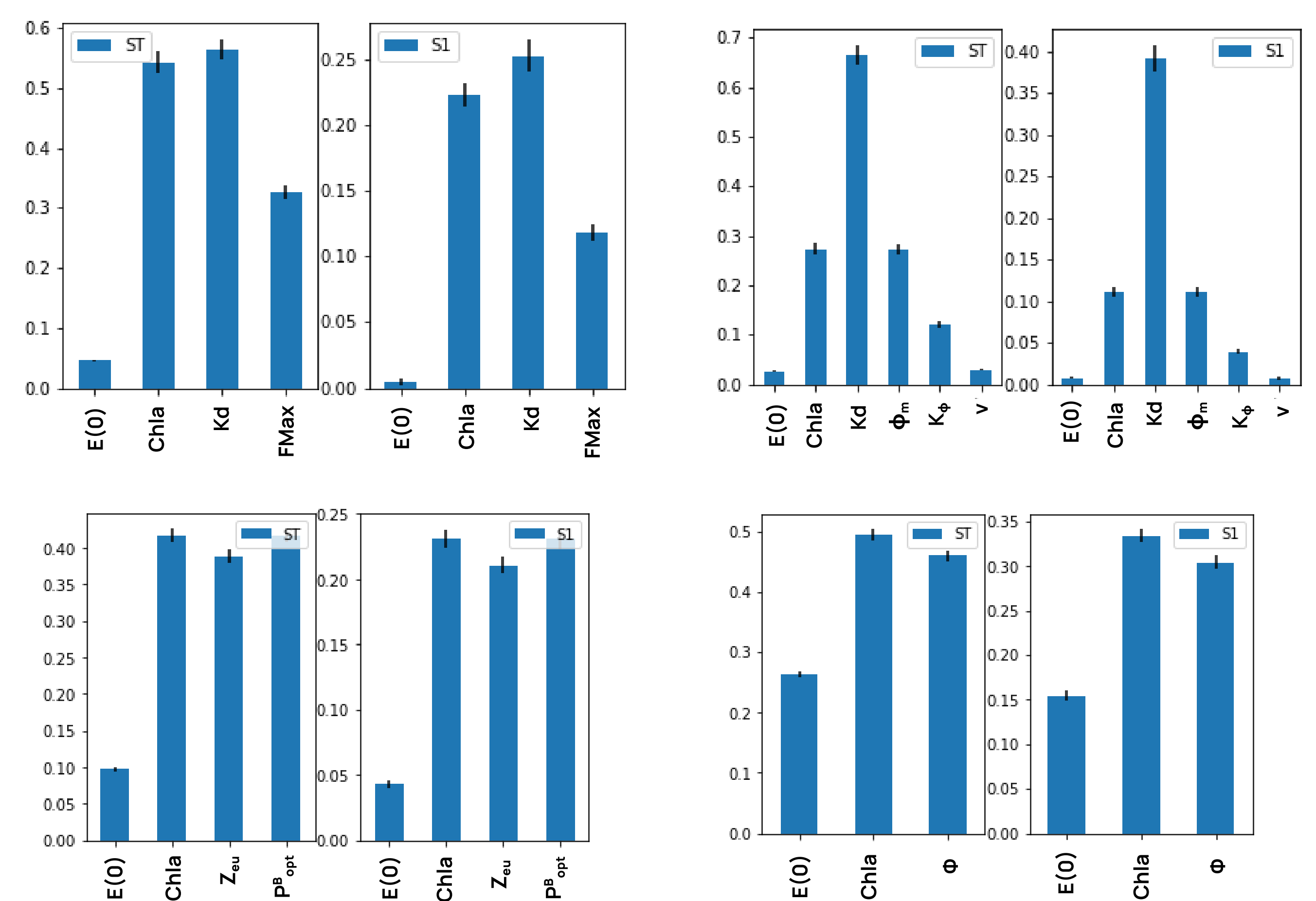


Figure 3. First (S1) - and total order (ST) sensitivity indices of primary production models.

OUTLOOK

- The automated bio-optical profiler Thetis a) at the LÉXPLORE platform (Minaudo et al. 2021; Wüest et al. 2021) continuously measures the inherent optical properties of the water column.
- Such high resolution data allows a finer tuning and understanding of PP-models b).

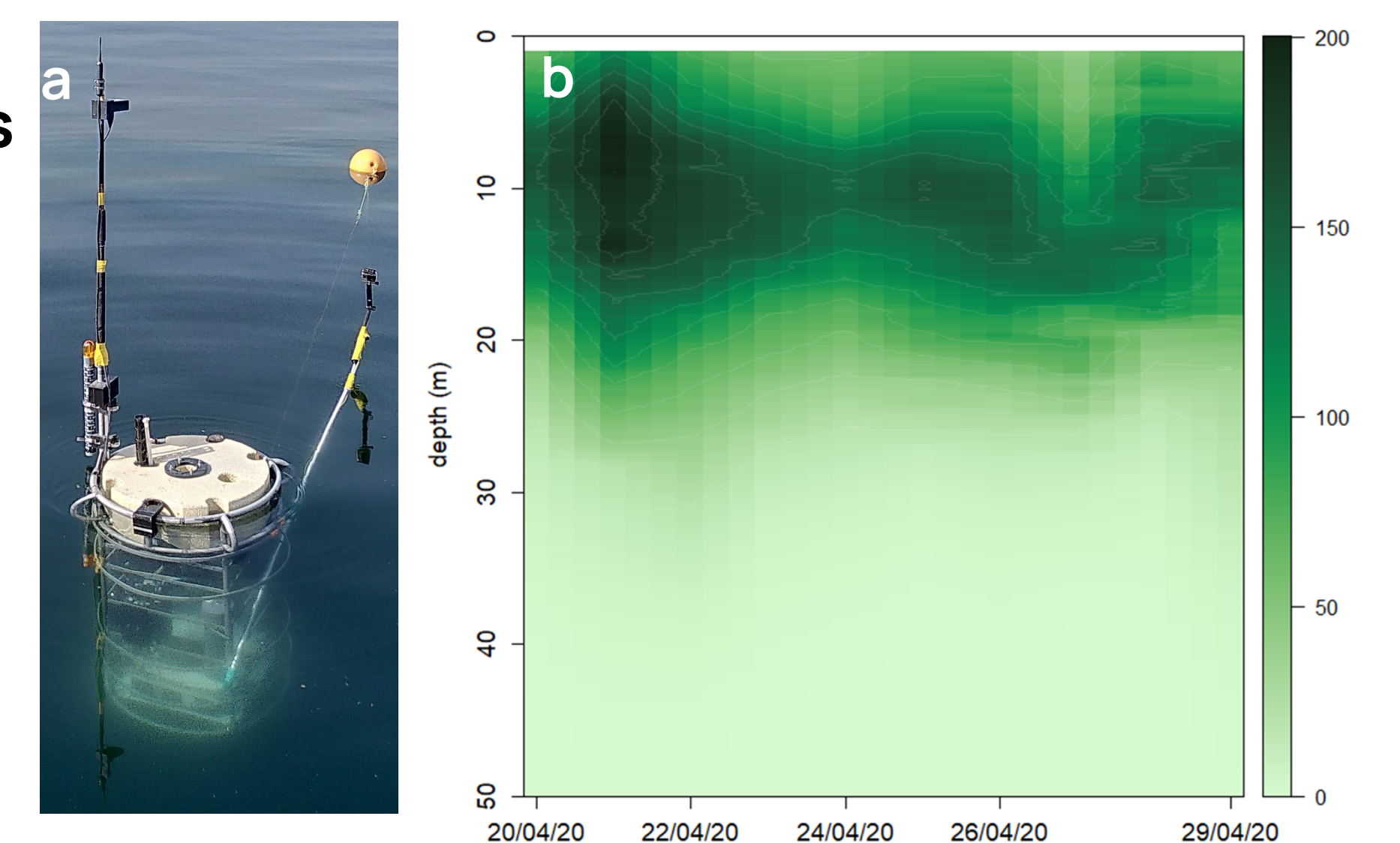


Figure 3. a) Autonomos profiler Thetis, b) primary production model by Arst using Thetis input data.

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