Method description for the calculation of primary production rates

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This document presents a general overview of the different steps that were used to calculate primary production using data collected during the Transsiz cruise. Note that all the calculations have been done in R and that all the code is available at the following address:

https://github.com/PMassicotte/transsiz

Photosynthetic parameters

Photosynthetic parameters have been determined from the P vs E curves obtained according to a method derived from Lewis and Smith (1983) both on water samples taken from the rosette and ice core bottom (last cm, see an example in Fig. 1). Some samples were also collected directly under the ice (UISW).

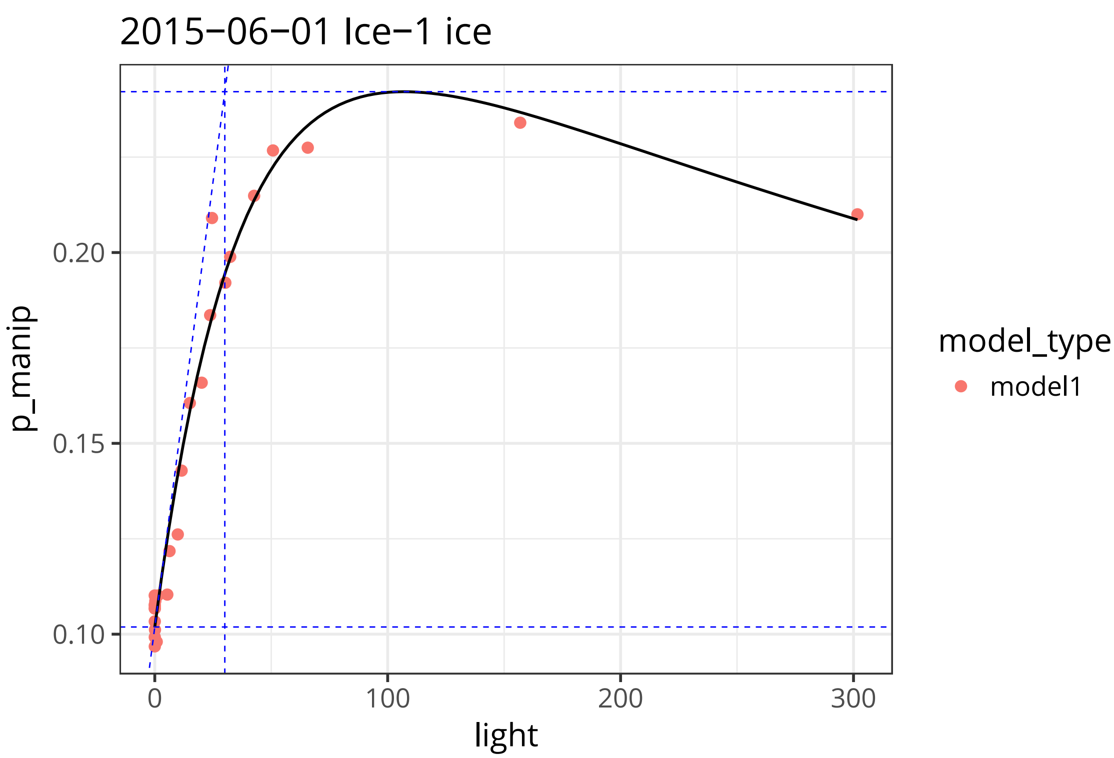

Figure 1: Example of a fitted PvsE curve.

Two different models based on the original definition proposed by (Platt et al., 1980) were used depending on the situation.

Model with photoinhibition

When apparent photo-inhibition was present, a model including two exponential was fitted (equation 1).

$$p = ps \times (1 - e^{-\alpha \times \frac{light}{ps}}) \times e^{-\beta \times \frac{light}{ps}} + p0 \tag{1}$$

Model without photoinhibition

When no apparent photo-inhibition was present, a model including only one exponential was fitted (equation 2).

$$p = ps \times (1 - e^{-\alpha \times \frac{light}{ps}}) + p0 \tag{2}$$

The non-linear fitting was done using the Levenberg-Marquardt algorithm implemented in the minpack.lm R package (Timur2016).

Ice transmittance

Ice transmittance was measured by the ROV at 8 different stations (Fig. 2). At each station, we used an average transmittance value to calculate the light just bellow ice cover. To remove the effect of ice hole where the ROV was deployed, we excluded measurements in a radius of 3 meters around the 0, 0 coordinates. This correspond to the red circles in Fig. 2. We also only conserved observations between 0.7 and 3 meters to avoid including transmittance measured a high depths.

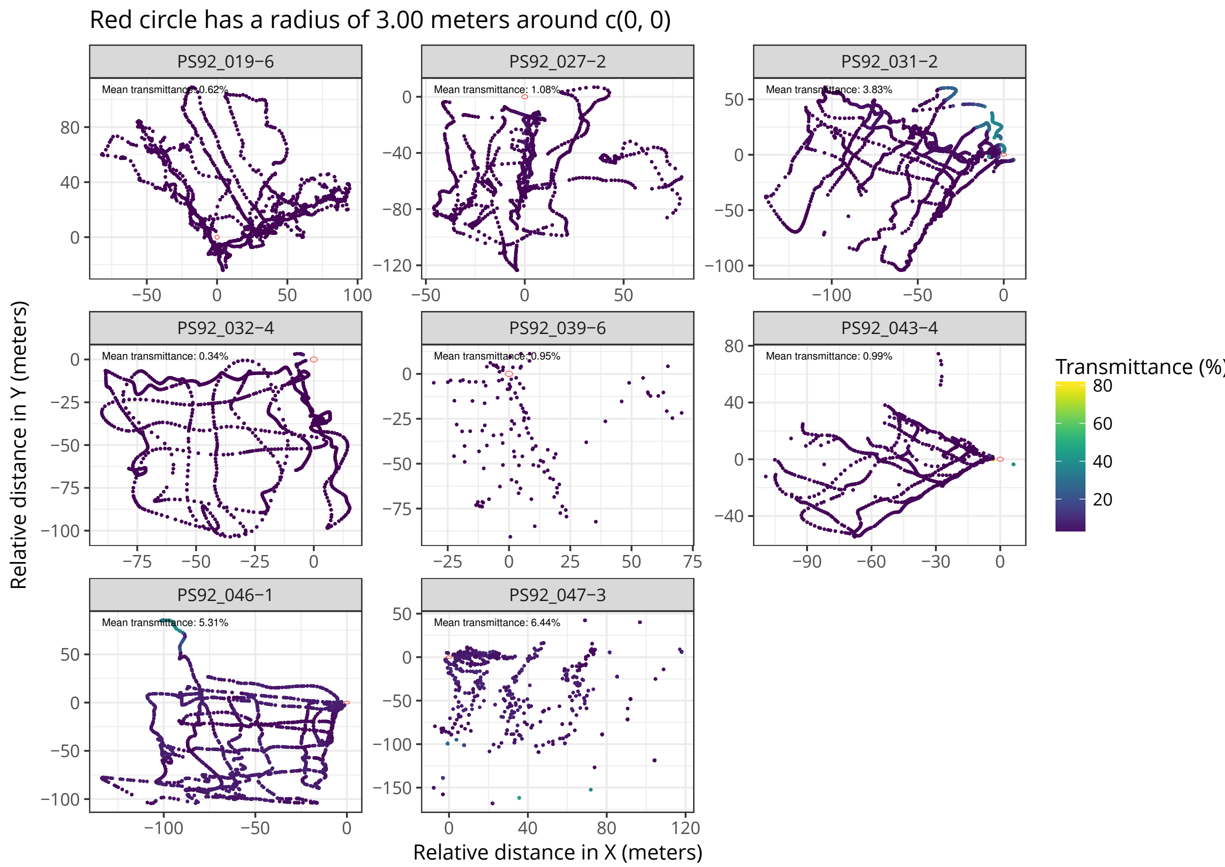

Figure 2: Transmittance at each position of the ROV for each stations sampled.

Estimation of KdPAR

Estimations have been done on irradiance measured by the ROV using files containing `rov_irrad` in their name. At each station, during the deployment, the ROV made one vertical profile (Fig. 3). We extracted the profile data visually by exploring the graphics of depth as a function of time (Fig. 3).

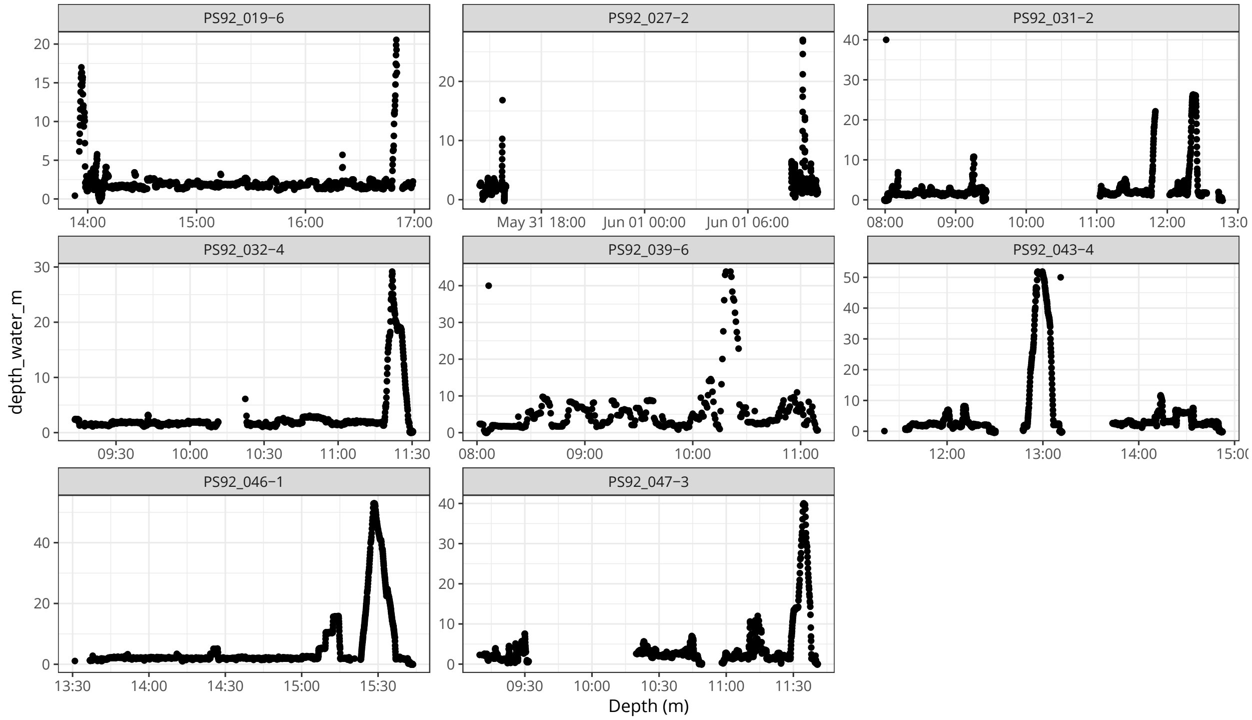

Figure 3: Depth of the ROV as a function of the time.

Then, PAR has been calculated by integrating irradiance data between 400 and 700 nm. The calculated PAR can be view in Fig. 4. Finally, Kd PAR (m^{-1}) has been calculated using equation 3.

$$\mathrm{PAR} = a \times e^{-\mathrm{kd} \times \mathrm{z}} \tag{3}$$

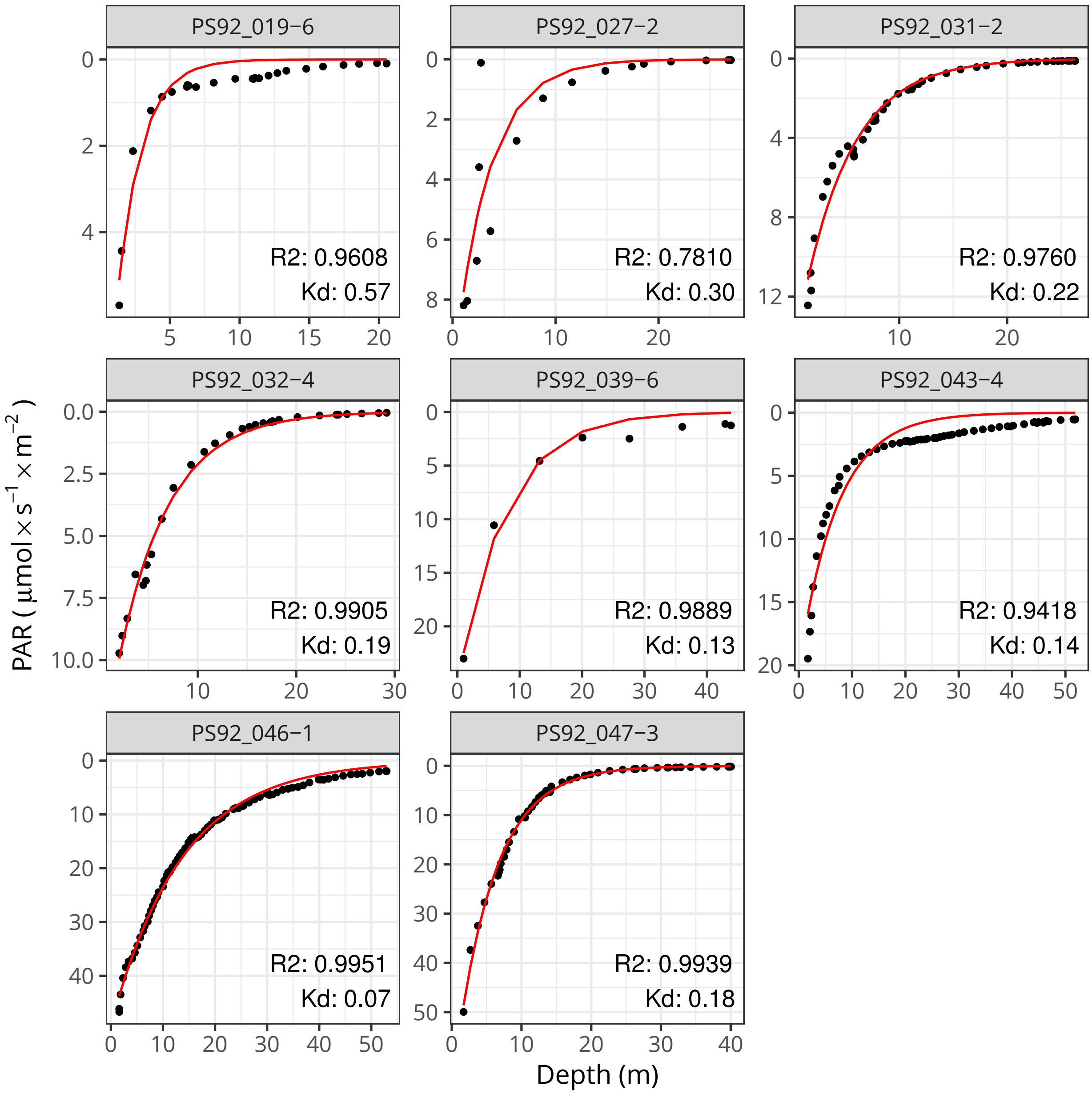

Figure 4: PAR as a function of depth. The calculated kd as been used to propagate PAR light measured by the pyranometer (see next section).

Pyranometer

Photosynthetic available radiation (PAR) just bellow ice was derived from the total energy measured every 10 minutes over a period of 24 hours by the Polarstern weather station (Fig. 5). As a same station was sampled over two consecutive days, we decided to average the PAR measurements over those two days in order to make the calculations for water colummns and ice core samples with the same theoretical light (Fig. 5).

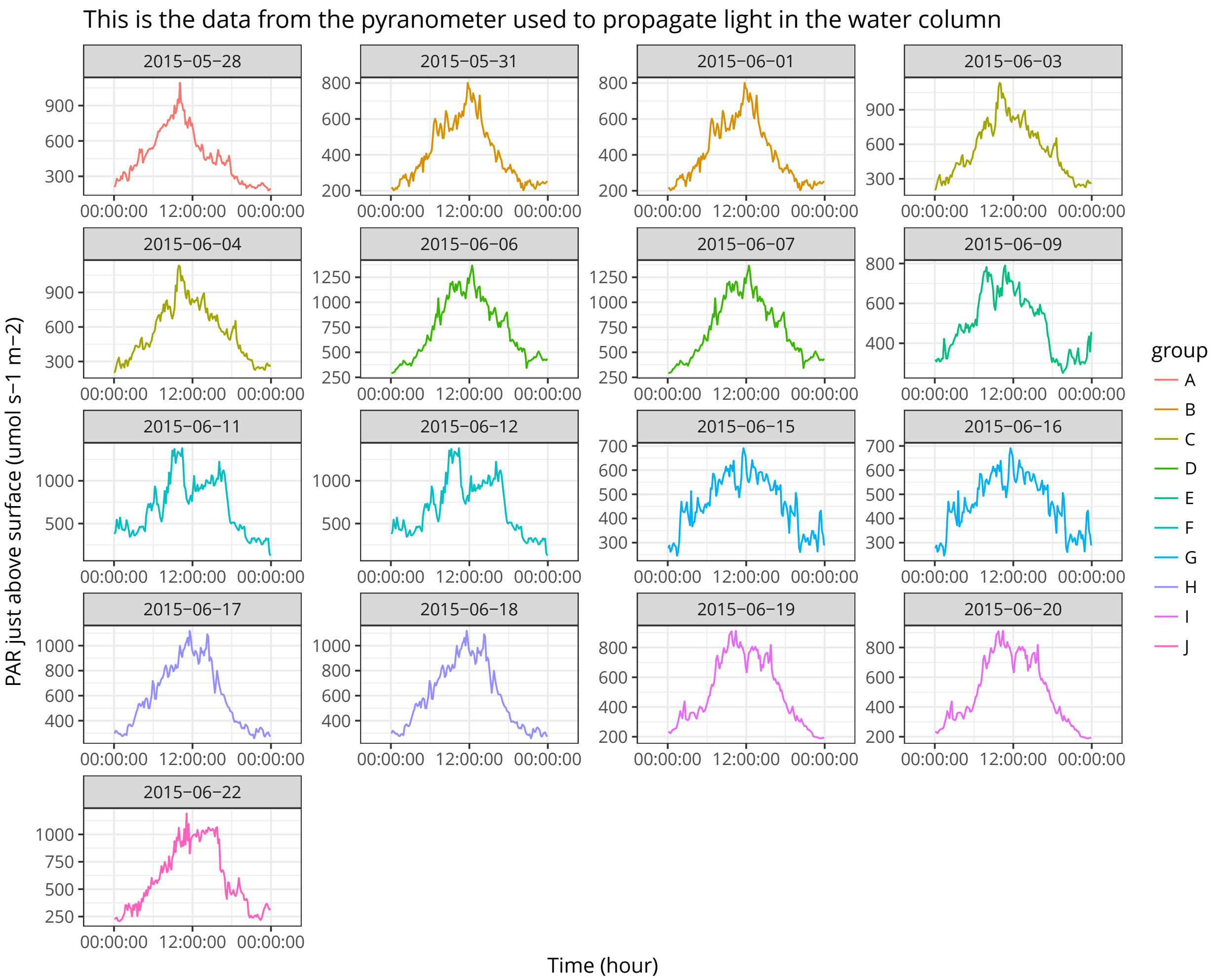

Figure 5: PAR just above the surface measured by the pyranometer every 10 minutes and averaged over 48 hours station by station. Stations on May 28th and June 22nd have not been sampled for ice cores, therefore only one light profil is used.

In the raw data, measurement were done every 10 minutes and thus averaged to obtain hourly PAR (Fig. 6). Note that the PAR presented in Fig. 6 are corrected with transmittance, explaining lower values compared to those found in Fig. 5.

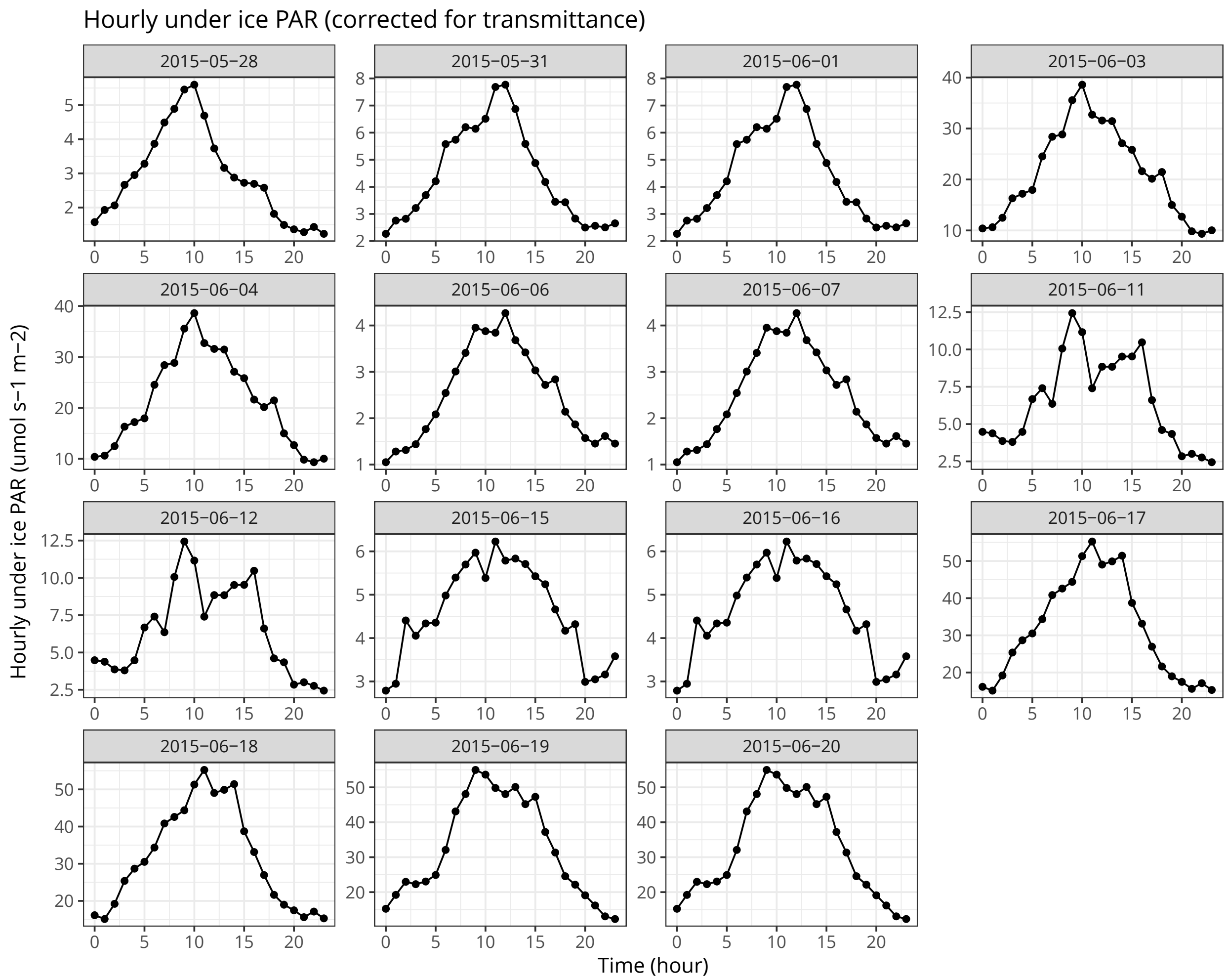

Figure 6: Hourly PAR just below the ice at each hour of the day.

Primary production

At each depth primary production was estimated using photosynthetic parameter, kd and PAR estimates. First, PAR was propagated at depth where PvsE curves were measured (Fig. 7). For ice samples, we used the light estimated just under the ice.

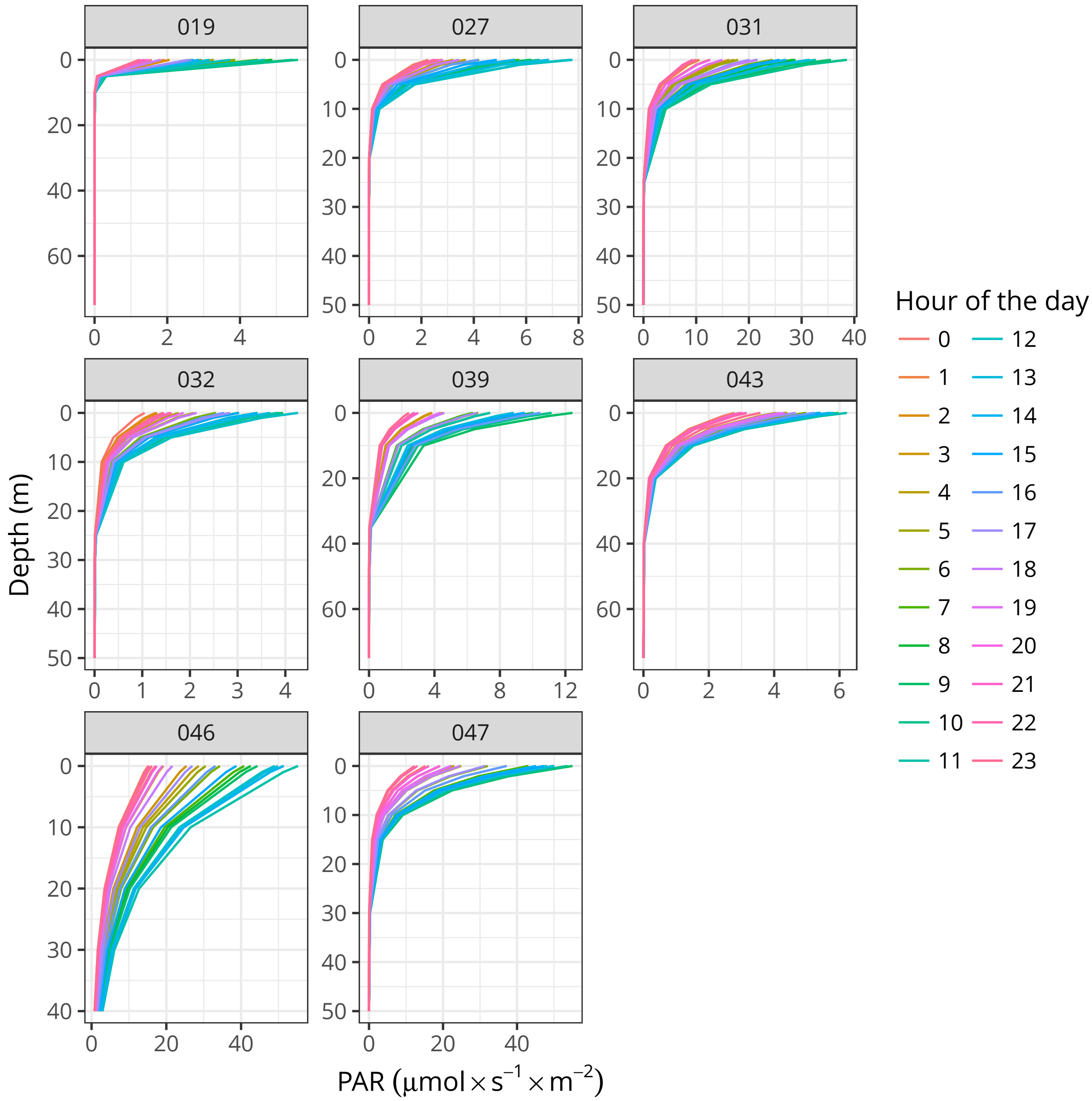

Figure 7: Propagated PAR in the water column.

Then, daily primary production at each depth at each hour was calculated using equation 4.

$$p = ps \times (1 - e^{-\alpha \times \frac{light}{ps}}) \tag{4}$$

Daily integrated primary production was calculated by summing primary production at each depth over a 24 hours period (Fig. 8).

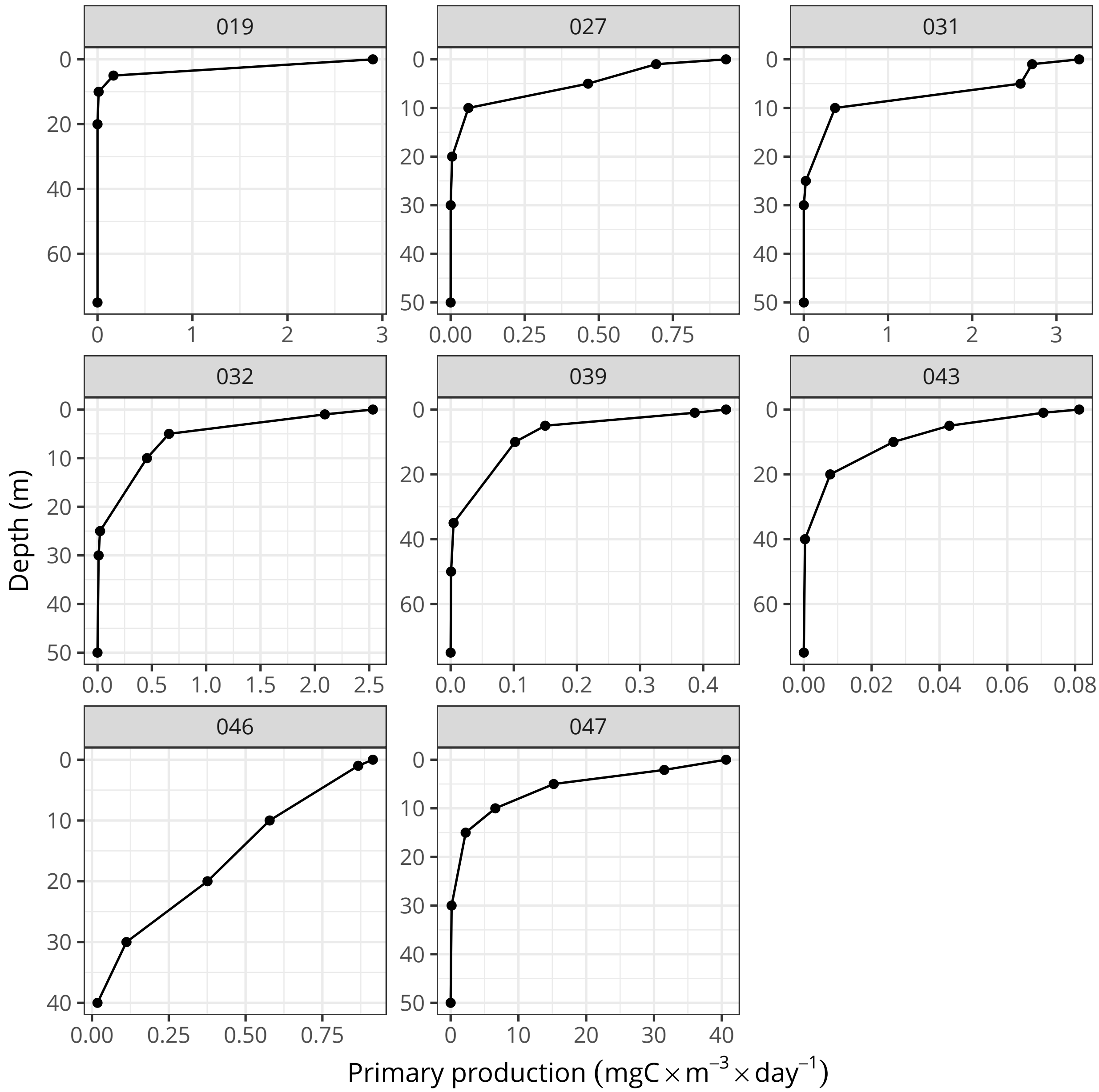

Figure 8: Daily primary production at depths where photosynthetic parameters were measured.

Finally, depth integrated primary production was calculated by integrating daily primary production over the water column. Final values for the water samples looks like this ($\mathrm{mgC} \times \mathrm{m}^{-2} \times \mathrm{day}^{-1}$):

station	pp
019	8.1834210
027	4.7891501
031	23.9609525
032	14.3760973
039	3.4981031
043	0.7353898

station	pp
046	15.2587445
047	239.1376043

Ice sample

Please note that unit for primary production for ice algea is cubic meter per day.

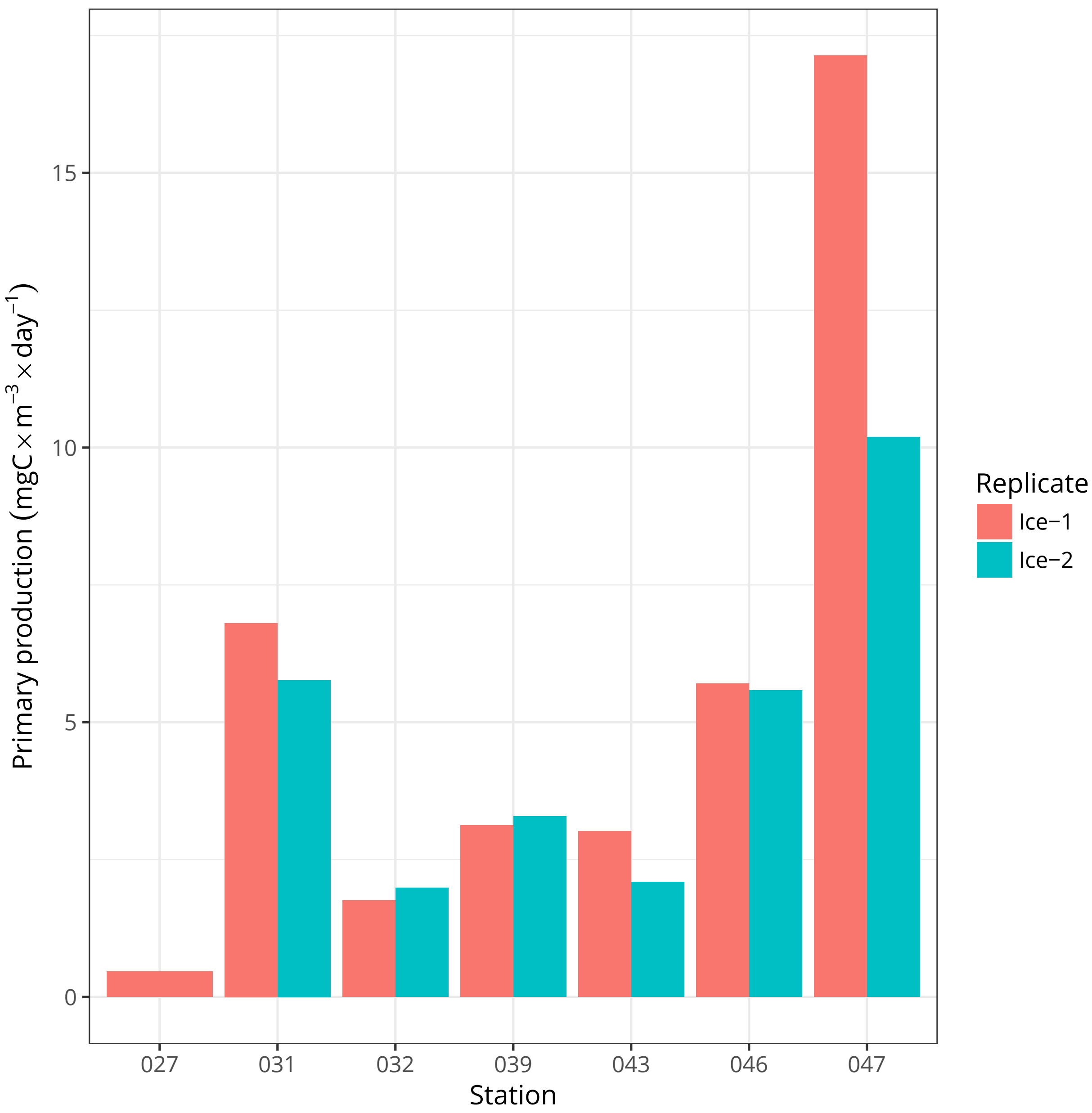

Figure 9: Daily primary production for ice algea.

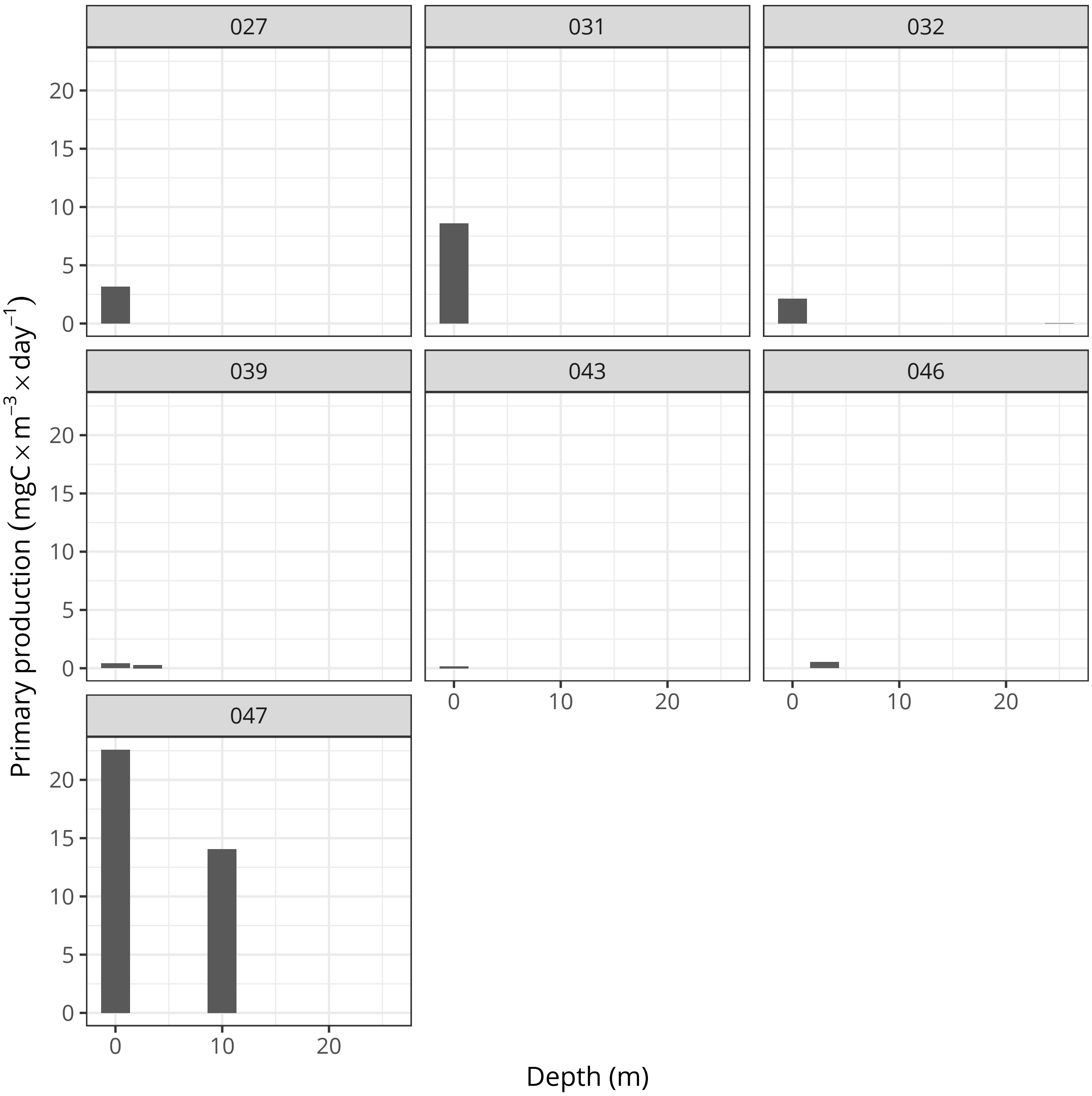

Figure 10: Daily primary production for phytoplankon sampled from the ice.

References

Lewis, M. R. and J. C. Smith (1983). "A small volume, short-incubation-time method for measurements of photosynthesis as a function of incident irradiance." Marine Ecology Progress Series 13: 99-102.

Plat, T., C.L. Gallegos and W.G. Harrison (1980). Photo-inhibition o photosynthesis in natural assemblages of marine phytoplankton. J. Mar. Res. 38:687-701.

Timur V. Elzhov, Katharine M. Mullen, Andrej-Nikolai Spiess and Ben Bolker (2016). minpack.lm: R Interface to the Levenberg-Marquardt Nonlinear Least-Squares Algorithm Found in MINPACK, Plus Support for Bounds. R package version 1.2-1. https://CRAN.R-project.org/package=minpack.lm uisw