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Chlorophyll *a* and macro-nutrient concentrations and photosynthetically active radiation during the training vessel *Umitaka-maru* cruises of the 58th Japanese Antarctic Research Expedition in January 2017

Ryosuke MAKABE[1, 2]*, Shintaro TAKAO[1, 2], and Tsuneo ODATE[1, 2]

[1] National Institute of Polar Research, Research Organization of Information and Systems, 10–3 Midori-cho, Tachikawa, Tokyo 190-8518.

[2] Department of Polar Science, School of Multidisciplinary Sciences, The Graduate University for Advanced Studies (SOKENDAI), 10–3, Midori-cho, Tachikawa, Tokyo 190-8518.

*Corresponding author: Ryosuke Makabe (makabe@nipr.ac.jp)

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Abstract: Chlorophyll *a* concentration is the most common indicator of phytoplankton biomass, fundamentally regulated by macro-nutrients and light intensity. Therefore, long term monitoring of these parameters gives us basic information on ecosystem changes with climate changes. As part of the monitoring programs of the Japanese Antarctic Research Expedition (JARE), chlorophyll *a* concentration and macro-nutrients (nitrate, nitrite, phosphate and silicic acid) have been measured on board icebreakers Fuji and Shirase since JARE-14 (1972/73 season) and JARE-7 (1965/66 season), respectively. The same monitoring has also been conducted during the cruise of the training vessel (T/V) *Umitaka-maru*, Tokyo University of Marine Science and Technology since JARE-55 (2013/14). The course of the Umitaka-maru is almost same every year; leave from Fremantle, goes down to ice edge (ca. 65°S) along 110°E meridian and back to Hobart, covering sub-tropical to polar waters in the Southern Ocean. During the cruise, water sampling from underway pump for chlorophyll *a* and macro-nutrient concentrations were obtained twice a day, and photosynthetically active radiation was continuously measured by a sensor mounted on the navigation bridge deck of the ship. The vertical water sampling for chlorophyll *a* concentration were conducted at 6 stations along 110°E meridian, although macro-nutrients concentration at the same stations was determined by another monitoring program. This report is the latest data collected during the T/V *Umitaka-maru* cruise in 2016/17 season.

1. Background & Summary

The phytoplankton community is the main primary producer in oceanic ecosystems. Their productivity can affect not only heterotrophic communities but also Air-Sea CO_2 flux. Phytoplankton biomass has usually been monitored by chlorophyll *a* concentration, which is a common indicator, in various coastal and oceanic regions. In the Indian Sector of the Southern Ocean, inter-annual changes in chlorophyll *a* were evident on a cycle of less than 10 years (Hirawake et al., 2005)[2]. This means that frequent observation of chlorophyll *a* is needed for understanding ecosystem responses to not only long term climate changes (e.g. global warming) but also decadal environmental changes (e.g. El Niño and Southern Annular Mode). In such phytoplankton observation, size fractionated chlorophyll *a* measurements are important, because both global warming and changes in sea ice dynamics affect on phytoplankton size spectrum (Montes-Hugo et al., 2008; Daufresne et al., 2009; Moran et al., 2010)[5; 1; 6]. Macro-nutrients and photosynthetically active radiation, which would also varied with climate changes in the surface mixed layer, are essentials for phytoplankton growth. A model study, for example, suggested that dominant factors affecting predicted changes in phytoplankton biomass and the structure from 1980 to 2100 are nutrients and temperature in the equator to mid latitude regions and light and temperature in the marginal sea-ice to subpolar regions, respectively (Marinov et al., 2010)[4]. Therefore, these measurements with chlorophyll *a* concentration and the size composition enable us better understand of spatio-temporal variability in phytoplankton biomass.

One of the routine observation program of the Japanese Antarctic Research Expedition (JARE), named “Biological Oceanography”, which was renamed to the monitoring observation “Marine Ecosystem Monitoring” from JARE-38. Chlorophyll *a* concentrations have been measured on board icebreakers Fuji and Shirase from JARE-14 in the 1972/73 season under routine monitoring observations. Chlorophyll *a* concentration has been closely related to water column structure (e.g., temperature and salinity) and macro-nutrients (nitrate, nitrite, silicic acid and phosphate), which has been measured under the other routine observation programs, “Physical Oceanography” and “Chemical Oceanography” started from JARE-7 in the 1965/66 season. “Physical Oceanography” and “Chemical Oceanography” were terminated on Shirase from JARE-51 and restarted as routine observation program “physical and chemical oceanography” using the training vessel (T/V) *Umitaka-maru*, Tokyo University of Marine Science and Technology since JARE-54 (2012/13). We also started the marine ecosystem monitoring during the same cruise on JARE-55 (2013/14).

This report mainly documents the phytoplankton chlorophyll *a* concentration in seawater at depths shallower than 200 m, measured during a cruise by the training vessel *Umitaka-maru* of the Tokyo University of Marine Science and Technology (UM1608) as part of the 58th Japanese Antarctic Research Expedition (JARE-58) in the austral summer of 2016/17. The chlorophyll *a* concentration was measured in two series: (1) spatial variations in chlorophyll *a* within the surface

water along the cruise track, and (2) vertical profiles of chlorophyll *a* in the Indian sector of the Southern Ocean.

The similar data sets collected by previous JARE have been published in JARE DATA REPORTS (e.g., Makabe et al., 2017)[3].

2. Study sites

Field sampling was conducted from Fremantle to Hobart during the UM16-08 cruise in January 2017. Surface waters from the underway pump, whose inlet was located at 5 m depth, were generally sampled twice a day along the cruise track (Fig. 1). Vertical water sampling was conducted at 6 sites (KC1-6) located along 110°E meridian from 40°S to ca. 65°S (Ice edge) (Fig. 1). Water sampling at KC2 (45°S, 110°E) was canceled because of heavy weather. Geographical settings of the stations were described in Shimada et al.[8] (submitted to Polar Data Journal).

3. Materials and methods

3.1. Chlorophyll *a*

Surface seawater was collected twice a day during the cruise from water that was continuously pumped through the vessel from an intake in the hull. At stations where water-column water sampling was performed, surface seawater was collected in a plastic bucket. Water samples were collected over the upper 200 m of the water column by Niskin bottles attached to CTD/Carousel Water Sampling System, which is a 24-position Carousel water sampler with CTD (SBE9plus, Sea-Bird Electronics, Inc.). On all occasions, water samples were collected from two dark bottles, and filtered onto glass-fiber filters (Whatman, GF/F), while size-fractionated samples were collected onto membrane filters (Whatman Nuclepore Track-Etch Membrane, pore size: 10 and 2 μm) and a Whatman GF/F. The filters were immediately soaked in N, N-dimethylformamide (Suzuki and Ishimaru, 1990)[9] and pigments were extracted for 1-20 days. The samples were stored in a freezer (–18°C) until analysis on board. Concentrations of chlorophyll *a* were determined fluorometrically (Welschmeyer, 1994)[10] with an on-board fluorometer (10-AU; Turner Design, Sunnyvale, California, USA). The fluorometer was calibrated against a chlorophyll *a* standard (Wako Chemical Co.) at a laboratory on land before the cruise, using a spectrophotometer and the specific absorption coefficient of chlorophyll *a* (Porra *et al.*, 1989)[7]. The results of the fluorometer calibration are shown

in Fig. 2. Fluorescence of all samples was higher than the minimum fluorescence during the calibration (0.517).

3.2. Macro-nutrients

Surface seawater for macro-nutrient analysis was collected at the same time when seawater for chlorophyll *a* was sampled. Nutrients measurements at 6 stations were conducted as part of JARE routine observation (Shimada et al., 2018)[8]. The surface water was stored at -18°C until analyses on the land laboratory. The analytical method after melting frozen samples was according to Shimada et al.[8] (submitted to Polar Data Journal). Precision in the coefficient of variation from the replicate analyses using 5 replicates of nitrate, nitrite, silicic acid and phosphate was 0.18%, 0.29%, 0.16% and 0.13%, respectively. Detection limit of nitrate, nitrite, silicic acid and phosphate was 0.05 µmol kg^{-1}, 0.01 µmol kg^{-1}, 0.15 µmol kg^{-1}, 0.007 µmol kg^{-1}, respectively.

3.3 Photosynthetically Active Radiation

Photosynthetically Active Radiation (PAR) at the sea surface was measured by a Pocket-size PAR logger (DEFI2-L, JFE Advantech CO., Ltd.) mounted on the navigation bridge deck of the ship. The detection limit and accuracy of the logger is 0.2 µmol m^{-2} s^{-1} and ±4.0% (0-2000 µmol m^{-2} s^{-1}), respectively.

4. Data Records

Chlorophyll *a* concentration and the size composition in vertical and surface waters are shown in Figs. 3 and 4, respectively. Macro-nutrients concentration in surface water and PAR at the sea surface are shown in Figs. 5 and 6, respectively. All measurements are presented in three data sheets, Surface, Stations and PAR. The fields in the data sheets are:

Cruise name – the cruise code of the vessel
JARE number – the JARE number of this sampling season
Ship name – the name of the ship on which the sampling was conducted
Station number – the name of the station on which the sampling was conducted
Latitude – the decimal latitude of the sampling station (negative value for South)
Longitude – the decimal longitude of the sampling station (positive value for East)
Sampling year – the sampling year
Sampling month – the sampling month
Sampling day – the sampling day

Sampling hour – the sampling hour (UTC)

Sampling minute – the sampling minute (UTC)

Chl. *a* bulk – total chlorophyll *a* concentration (μg l^{-1})

Chl. *a* >10 μm – proportion of chlorophyll *a* in >10 μm fraction (%)

Chl. *a* 2–10 μm – proportion of chlorophyll *a* in 2 – 10 μm fraction (%)

Chl. *a* <2 μm – proportion of chlorophyll *a* in <2 μm fraction (%)

Nitrate – concentration of nitrate (μmol kg^{-1})

Nitrite – concentration of nitrite (μmol kg^{-1})

Silicic acid – concentration of silicic acid (μmol kg^{-1})

Phosphate – concentration of phosphate (μmol kg^{-1})

Sampling depth – the depth of water collection (m)

PAR – Photosynthetically Active Radiation (μmol m^{-2} s^{-1}) at the sea surface

5. Author contribution

R. Makabe performed the processing of sample analysis and writing of the manuscript. T. Odate directed the monitoring program. S. Takao carried out the field sampling on board the T/V Umitaka-maru and the macro-nutrients analysis in the land laboratory.

6. Usage Notes

The data presented in this report are archived and available from the online Science Database of the National Institute of Polar Research (http://scidbase.nipr.ac.jp/?ml_lang=en). Permission to use these data for publication or presentation should be obtained in writing. Inquiries about details of the data record should be addressed to:

Tsuneo Odate

National Institute of Polar Research

Tel: +81-42-512-0738

E-mail: odate@nipr.ac.jp

Physical and Chemical data, such as temperature, salinity, dissolved oxygen, during the cruise can be referred to as Shimada et al.[8] (submitted to Polar Data Journal)

7. Competing interests

The authors declare no competing financial interests.

8. Figures

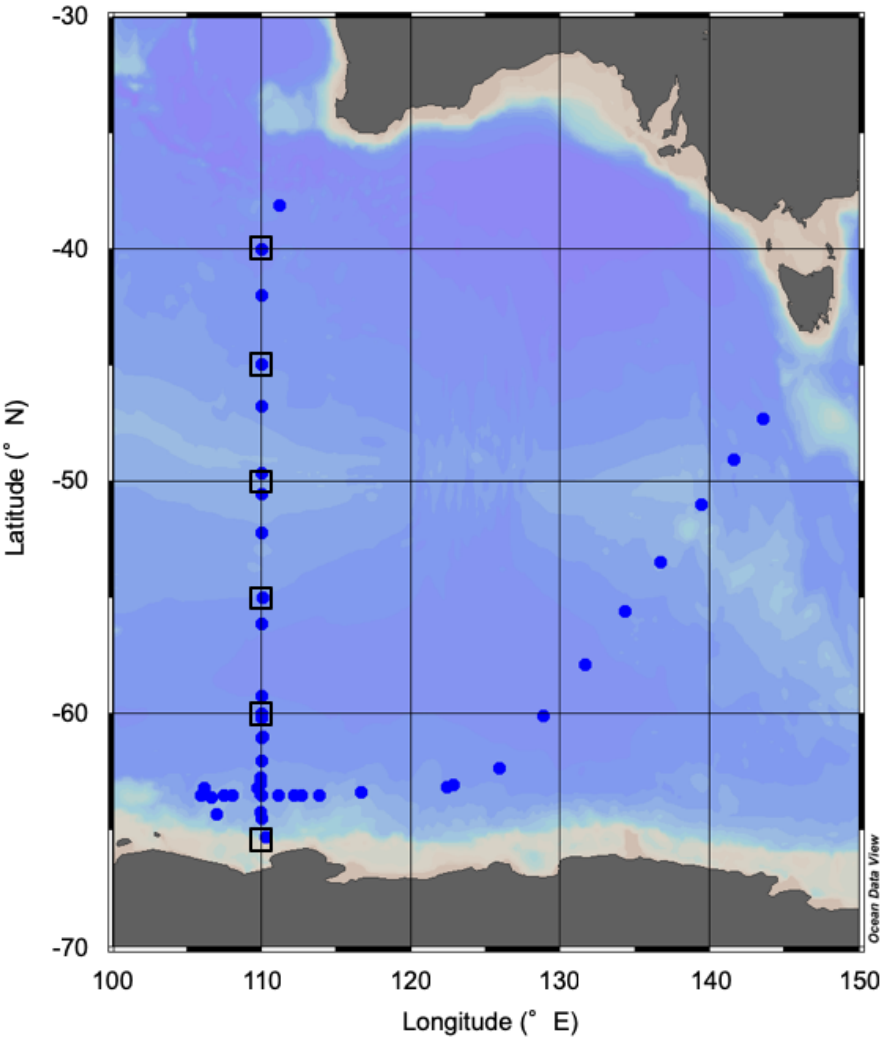

Fig. 1. Location of sampling sites during UM16-08 cruise. Open squares and blue circles show vertical and underway sampling stations, respectively.

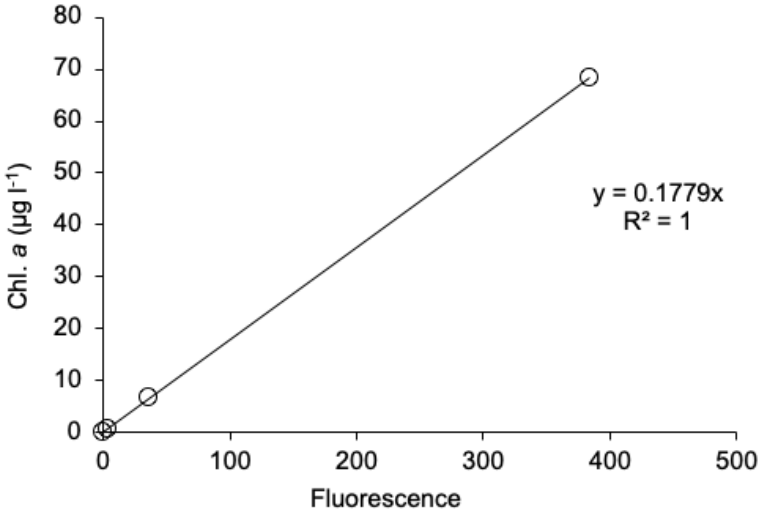

Fig. 2. Correlation between chlorophyll *a* and fluorescence during calibration of the fluorometer.

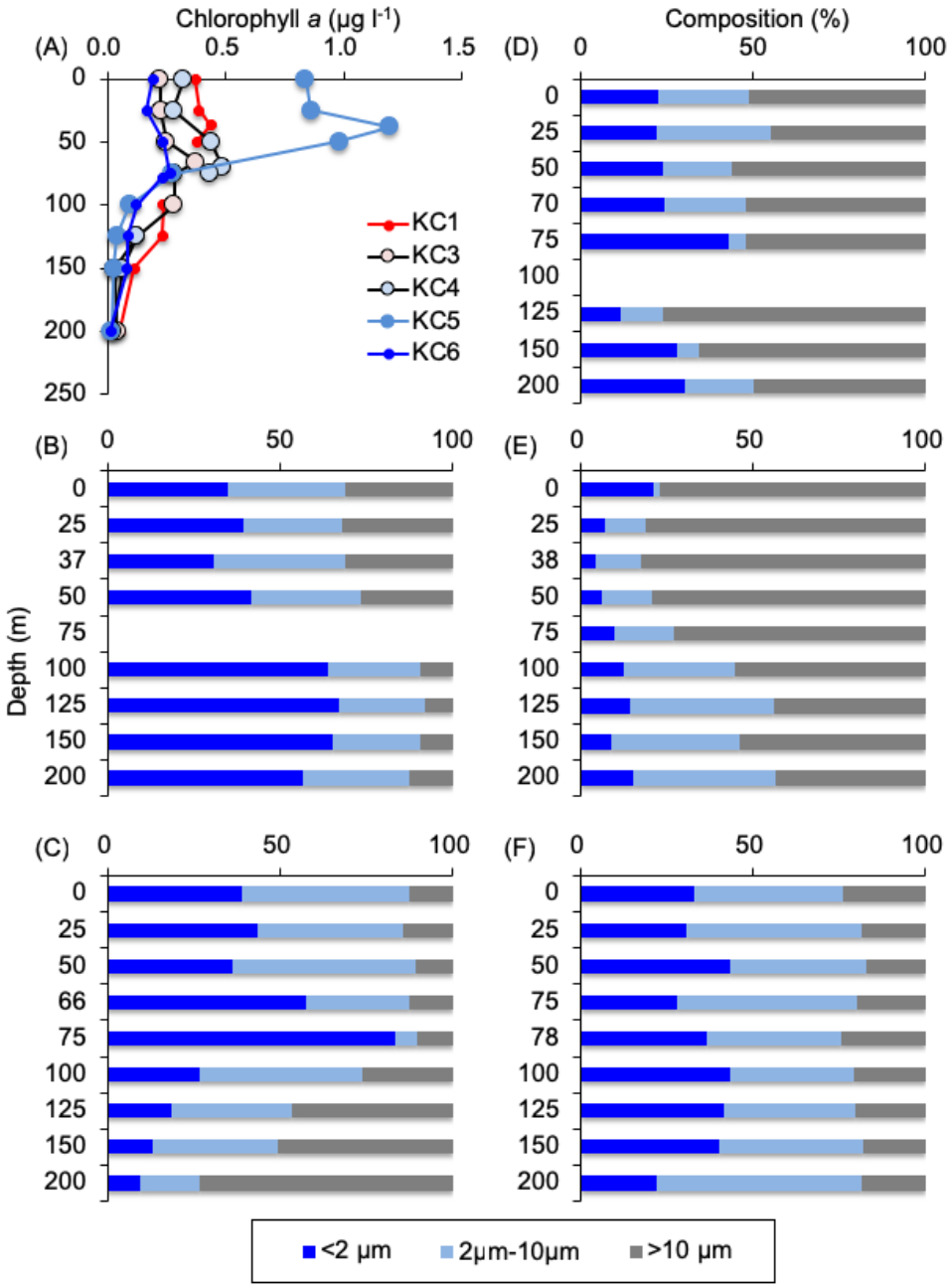

Fig. 3. Vertical profiles of chlorophyll *a* (A) and the size composition at KC1 (B), KC3 (C), KC4 (D), KC5 (E) and KC6 (F).

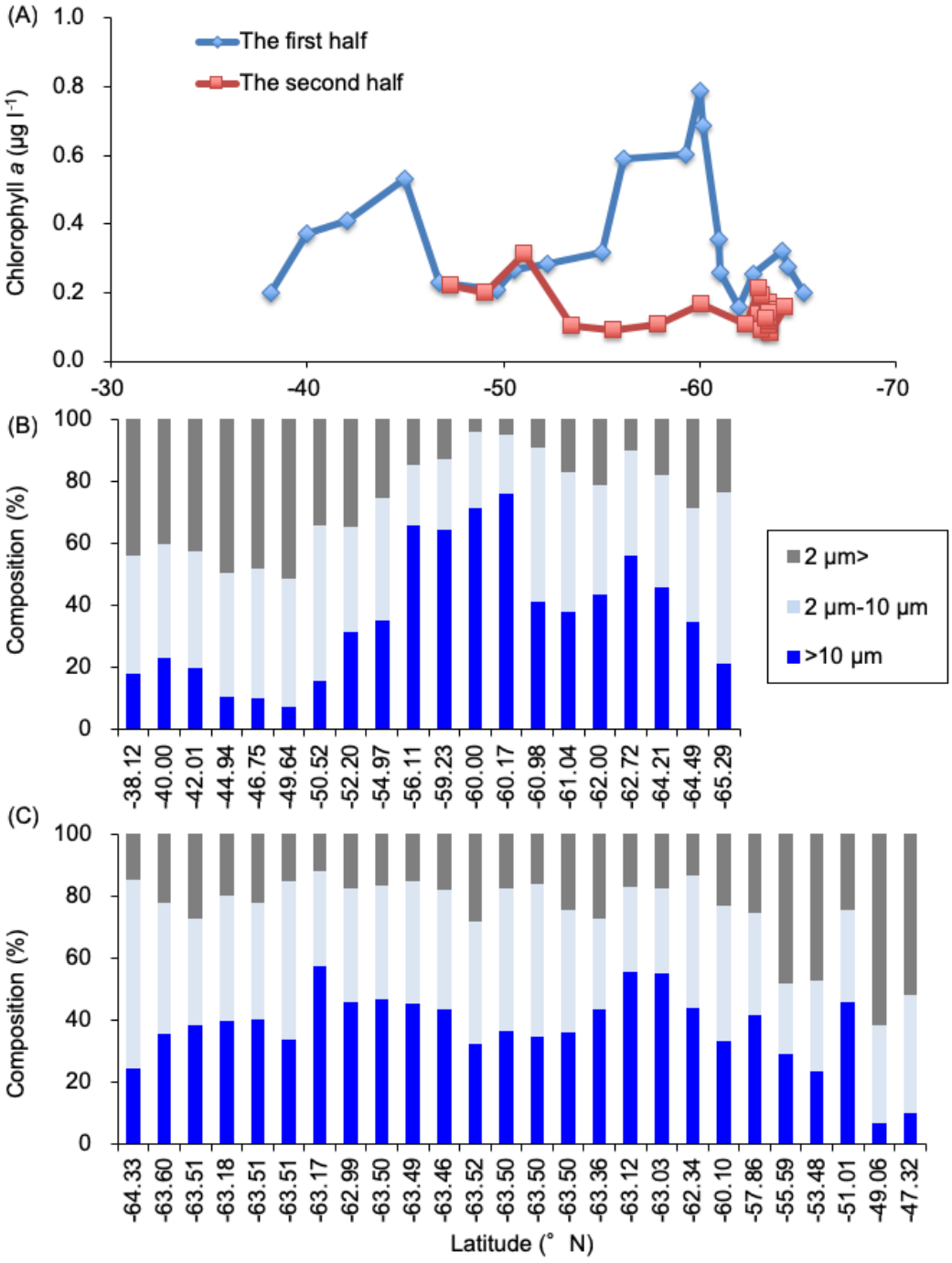

Fig. 4. Surface chlorophyll *a* concentration (A) and the size composition during the 1st (B) and the 2nd half (C) along the cruise track.

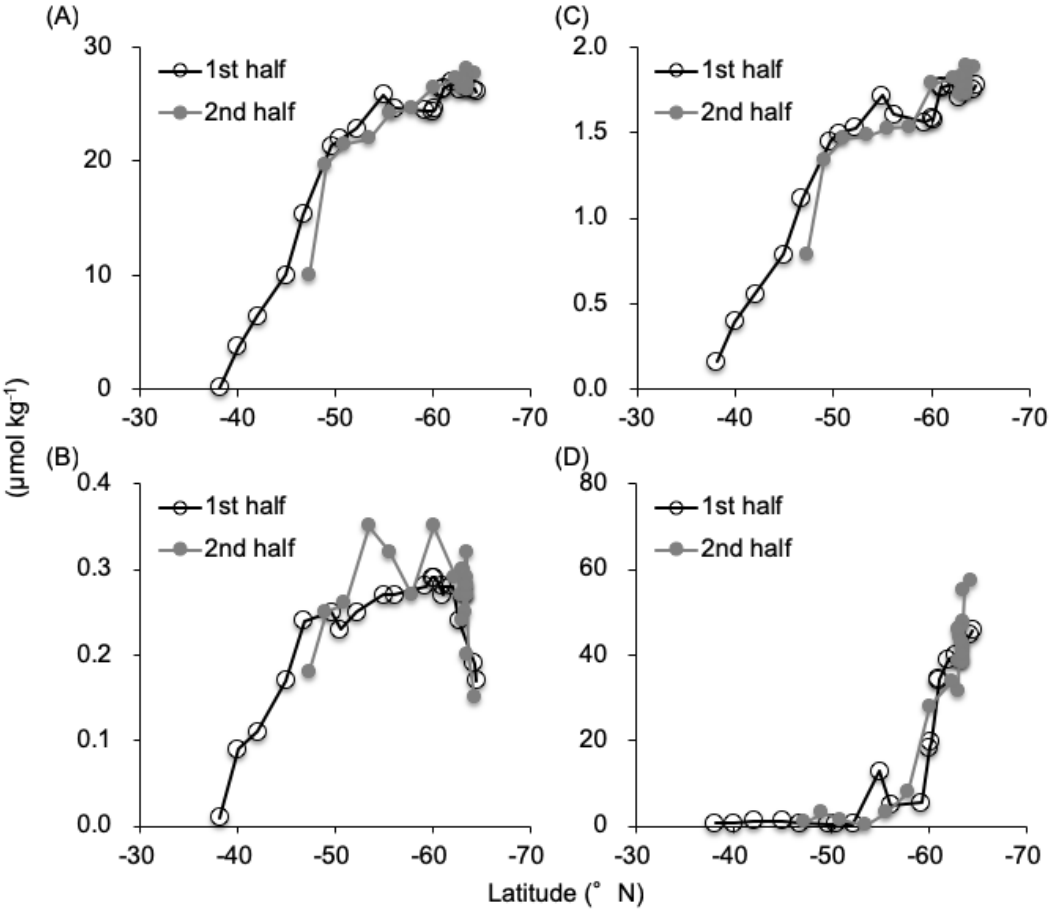

Fig. 5. Surface macro-nutrients concentration during the cruise. (A) nitrate, (B) nitrite, (C) phosphate, (D) silicic acid.

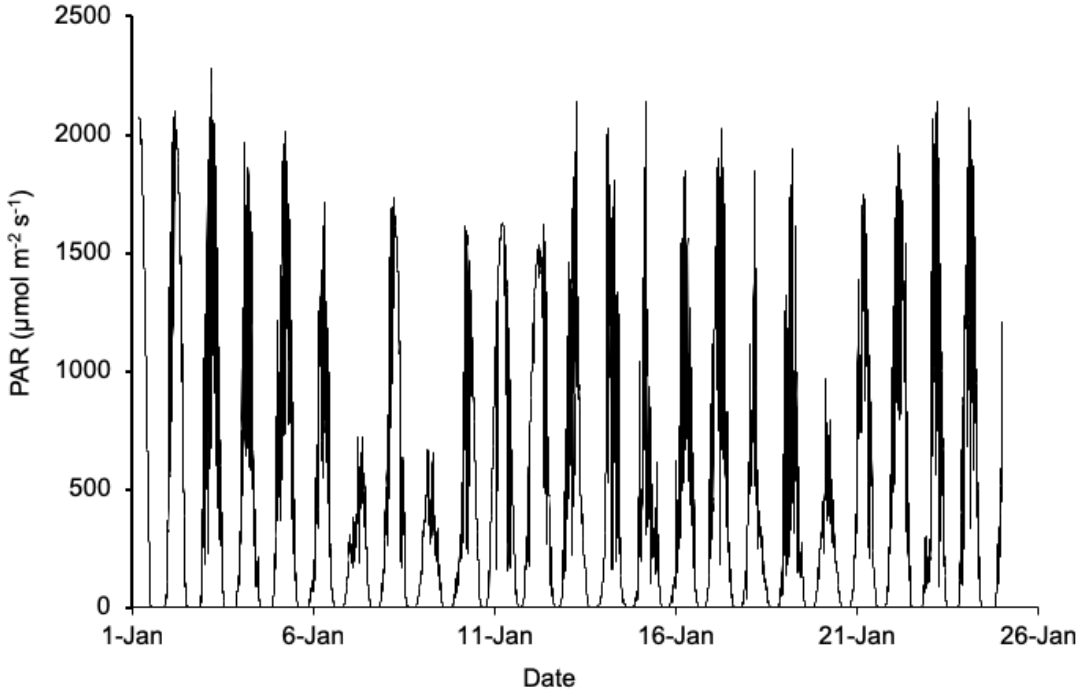

Fig. 6. Photosynthetically active radiation (PAR) at the surface during the cruise.

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