A Comparison of Decimeter Scale Variations of Physical and Photobiological Parameters in a Late Winter First-Year Sea Ice in Southwest Greenland

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Abstract: Small-scale variation in the physical and biological properties of sea ice was examined by collecting nine sea ice cores within 1 m² in a land-fast first-year ice in southwest Greenland in late winter. Cores were sectioned in four segments and sea ice physical, biological, and photobiological parameters were measured. The main purpose was to explore the decimeter-scale horizontal and vertical variations in common sea ice parameters. ANOVA analyses revealed significant within-core variations for bulk salinity, brine salinity, brine volume, gas volume, chlorophyll a (Chl a), and the maximum light-limited photosynthetic efficiency (α). Only temperature and bulk salinity variations were significant between cores, and no significant variations were found within or between cores for other photobiological parameters. Power analyses were applied to determine the number of replicates needed to achieve a significance at \( p < 0.05 \) with sufficient power, and showed a minimum of four and preferably five replicate cores to detect the observed variability in this first-year ice. It is emphasized that these results only apply to this type of first-year ice in late winter/early spring, and that different variations may apply to other types of ice.

Keywords: sea ice; physical and photobiological parameters; Phyto-PAM; spatial variability; Greenland

1. Introduction

Sea ice covers up to 10 percent of the surface of the earth at its maximum extent in both the Arctic and Antarctic [1,2]. It plays a fundamental and significant role in the earth’s climate, as exemplified by the high albedo of the ice, which reflects 50–80 percent of incoming radiation back into space [3]. Sea ice is an ecosystem, though ephemeral, with defined pathways and exchange of energy and matter [4]. A variety of organisms from polar bears to microscopic bacteria depend on sea ice for sustenance, including feeding, resting, and denning [5]. The autotrophic carbon production of sea ice is also essential as the only food source for higher marine trophic levels during late winter and early spring [6]. Furthermore, some 10 percent of the total marine-produced carbon is derived from ice algae; the specialized microscopic plants adapted to the very low light conditions at the bottom of the sea ice and inside the brine channels [7]. Sea ice is a three-phase material consisting of solid ice, brine water, and gas inclusions where temperature, light, and brine salinity clearly define the physical conditions for all organisms living inside or at the bottom of the ice [8]. The annual cycle of freezing-up during autumn and winter and the following melt in spring and early summer produce extremely large variations in sea ice parameters, but there is also substantial variation at small horizontal and vertical scales [9]. This spatial variation includes physical [10] and optical [11] parameters, biological parameter as chlorophyll a (Chl a) [8,12–15], a proxy for ice algae biomass [16], dissolved nutrients [17], CaCO₃ [18], sea...
ice photobiological parameters [19], and distribution of meiofauna in the ice [20]. Studies of the spatial variation of ice algae biomass have identified snow cover and thickness as the main driver of the variability [8,12–15], as snow regulates PAR transmittance in relation to the abundance, photobiological conditions, and species composition of the ice algae at the bottom of the ice [21,22]. The spatial scales applied in these studies have varied from a few meters or smaller [23,24] to several hundred meters [8,12] or kilometers in applying hierarchical sampling [24].

However, the patchiness of algal colonization can result in significant variation even at small (<1 m) scales, with uncertain implications for sampling strategies and necessary replication for detecting patterns of distribution and abundance. Small scale variations are also relevant in under-ice remote sensing regarding the footprint size of a given sensor [25]. Compared to other studies of spatial variability at the kilometer, decameter and meter scales mentioned above the present study is designed to answer the basic question: What is the variability of common sea ice parameters with depth in an ice core? We therefore apply a spatial scale of less than 1 m, i.e., we sampled nine cores within 1.0 m$^2$ and analyzed both the horizontal and vertical variation in physical, biological, and photobiological parameters. We explore the variation in parameters in cores sampled on land-fast first-year ice, and we address the questions: (1) what are the variations in parameters both between cores and within cores; (2) what causes this variation; (3) are there differences in the variation of physical, biological, and photobiological parameters between and within cores; and (4) how many samples are required from one sampling site to encompass the variation in a land-fast first-year ice?

2. Materials and Methods
2.1. Study Area and Sampling

Sampling was carried out 27 February 2020 on first-year land-fast sea ice near the village of Kapisillit, located in a branch of the Godthåbsfjord, Greenland, approximately 75 km east of the capital Nuuk (64°26.027′ N, 50°16.102′ W) (Figure 1). The weather was sunny, winds were 1–3 m s$^{-1}$ from the southeast, and air temperatures were around −17.0 °C. Kapisillit was chosen as sea ice and snow conditions resemble other locations in the Godthåbsfjord where sea ice studies have been conducted, such as the Kobbefjord [26] and Malene Bight [17]. Furthermore, the comparative meter and decameter spatial variations in sea ice and biogeochemical parameters have been studied previously at Kapisillit using Moran’s I coefficients [18]. In that study, bulk salinity showed no significant horizontal variations within <0.5 m during a March sampling and <1.0 m during a sampling in April [18].

The sampling design was to collect 9 cores of sea ice within a 1.0 × 1.0 m plot (Figure 2). The plot was marked out with wooden stakes, and snow depths were measured to the nearest 0.1 cm at 10 random spots within the square. The snow cover was gently removed with a shovel within the plot, and cores were collected in a random order using a Mark II KOVACS ice corer with an inner diameter of 90 mm. The cores were placed in a cutting frame and shaded with a black cloth to protect the ice from the high surface irradiance during processing. A 3 mm thick hole was drilled to the center of the ice core and temperature was determined to nearest 0.1 °C with a digital thermometer (Testo Thermometers). Temperatures were measured at 2.5, 7.5, 12.5, and 17.5 cm from the bottom of the ice core, which was then sectioned into four 5.0 cm thick segments with a stainless steel saw, with each segment placed in polyethylene containers, and returned to the laboratory in a lightproof box. All polyethylene containers were placed in a dark cold (3–4 °C) room for thawing of ice, and no filtered sea water was added. PAR transmittance through the snow and ice package was determined by drilling a hole with the KOVACS corer near the sampling plot, and measuring under-ice PAR with a Li-Cor 1400 PAR sensor on an L-arm, as well as downwelling PAR at the surface. This was done at two sites within 1 m from the sampling area. Upwelling PAR was measured with the Li-COR 1400 PAR sensor to calculate the albedo of the surface.
Volume, weight and bulk salinity (Ysi Pro Plus, www.ysi.com) were measured on samples melted at room temperature. Brine salinity, brine density, brine volume, and gas volume were derived based on the Cox and Weeks relations [27]. Mean and standard deviations were calculated for each of the parameters for the four segment groups, $x_1$, $x_2$, $x_3$, and $x_4$.

2.3. Chlorophyll Analyses

Chl $a$ concentration in the ice was determined by filtering 200 mL of the sample through glass fiber filters (GF/F, 25 mm) using a vacuum of <30 kPa. Filters with algae
were extracted in 10 mL 95% ethanol for at least 6 h, and the extract was centrifuged at approx. 1250 \( \times g \) both before and after acidification with 1 M HCl (3 drops applied to each sample, to ensure its full effect). A solid standard was measured three times throughout measurements to check that there were no changes in the calibration. Relative fluorescence units (RFU) of the supernatant was analyzed on a Turner Trilogy fluorometer (Turner, www.turnerdesigns.com). Chl \( \text{a} \) concentrations were integrated to derive the total biomass for each segment \( x_1 \), \( x_2 \), \( x_3 \), and \( x_4 \) with mean and standard deviations.

2.4. Photobiology

Photosynthetic parameters were assessed with a Walz Phyto-PAM II Pulse Amplitude Modulated fluorometer (Walz, www.walz.com), as described in detail previously [28,29]. In brief, the method is based on the principle of photons captured by chloroplast photosystems being used either in photosynthesis, released as heat, or fluorescing at longer wavelengths [29]. All PAM measurements were carried out in a darkened and cold room, and samples were kept in the dark at 4 \( ^\circ C \) during thawing and subsampled into cuvettes immediately before PAM measurements, to ensure dark adaptation. The instrument gain was regulated before each sample measurement and background noise removed using 0.22 \( \mu m \) filtered blanks of each sample. The procedures and protocols applied to determine the dark-adapted maximum fluorescence yield of Photosystem II (\( \Phi_{\text{PSII, max}} \)) and rapid light curves (RLC) were as described previously [28]. \( \Phi_{\text{PSII, max}} \) is an indicator of physiological condition and photoacclimation, and the relative electron transport rate (rETR) at increasing intensity of the actinic light source applied during RLCs is calculated as:

\[
\text{rETR} = 0.85 \times 0.5 \times \frac{\text{PAR}}{\Phi_{\text{PSII}}} \tag{1}
\]

where 0.85 is a PAR absorption coefficient, 0.5 relates to energy being divided between photosystems I and II in electron transport [28], and \( \Phi_{\text{PSII}} \) is the effective fluorescence yield of Photosystem II at each irradiance. The photoacclimation parameters \( \alpha \) (initial slope of the light-limited curve, illustrating the maximum photosynthetic efficiency) and \( \text{rETR}_{\text{max}} \) (the maximum electron transport rate at light saturation) were determined directly from RLCs, with \( E_k \) (the onset of light saturation) calculated as \( \text{rETR}_{\text{max}} / \alpha \) [29].

2.5. Data Analysis

One-way ANOVA was used to test for differences in physico-chemical and biological parameters both within and between cores. Prior to ANOVA, chl \( \text{a} \), \( \Phi_{\text{PSII, max}} \), \( \text{rETR}_{\text{max}} \), \( E_k \), and \( \alpha \) were all log-transformed to correct for heterogeneity of variances as revealed by Levene’s test. For those parameters where ANOVA revealed significant differences, post hoc Tukey tests were applied for identification of significantly differing means. All ANOVA and related tests were performed in JASP Version 0.11.1. To address the question of numbers of replicate cores required for future detection of significant differences while minimizing Type I and Type II errors, power analysis models were calculated for the significantly differing independent variables in the data (i.e., bulk salinity, chl \( a \), \( \text{rETR}_{\text{max}} \), and \( \alpha \)). Power analyses were run in GPower Version 3.1.9.6 [30], estimating \( n \) for the standard requirements of \( p < 0.05 \) and power \( (1 - \beta) = 0.80 \) [31].

3. Results

3.1. Physical, Biological, and Photobiological Parameters

The average ice thickness of the nine cores was 20.4 ± 0.7 cm with an average snow cover thickness of 16.9 ± 0.3 cm and an albedo of 0.82, and transmittance of 0.01 for the snow and ice package. This provided an under-ice irradiance of 6.73 \( \mu \text{mol photons m}^{-2} \text{s}^{-1} \) at the time of sampling as summarized in Table 1. There was a negative freeboard of about 1 cm.
Table 1. Ice thickness (n = 9), snow depth (n = 10) and optical conditions (n = 2) at the sampling site.

| Parameter            | X1        | X2        | X3        | X4        |
|----------------------|-----------|-----------|-----------|-----------|
| Ice Thickness        | 20.4 ± 0.7 cm |           |           |           |
| Snow depth           | 16.9 ± 0.3 cm |           |           |           |
| Surface PAR          |           |           | 673.1 ± 49.8 μmol photons m⁻² s⁻¹ |           |
| Transmittance        |           |           | 0.01 ± 0.001 |           |
| Albedo               |           |           | 0.82 ± 0.04 |           |

Descriptive statistics for the physical, biological, and photobiological parameters are shown in Table 2, and show a clear increase in sea ice temperature from coldest at the upper surface segment (x4) to warmest in the bottom (x1) segment in contact with the seawater. Note that some parameters are not independent, as brine salinity, brine density, brine and air volumes are based on relations which include temperature and bulk salinity [27].

Table 2. Mean ± SD (n = 9) for temperature, bulk salinity, brine density, brine channel volume, gas volume, Chl a, $\Phi_{PSII\text{-}max}$, $\alpha$, $rETR_{max}$, and $E_k$ for each of the four 5 cm-thick core segments (x1, x2, x3, and x4), where x1 is the lowest segment in contact with the sea water, and x4 is the upper segment in contact with the snowpack.

| Parameter                  | X1         | X2         | X3         | X4         |
|----------------------------|------------|------------|------------|------------|
| Temperature (°C)           | -2.58 ± 0.36 | -2.73 ± 0.27 | -2.86 ± 0.36 | -3.04 ± 0.38 |
| Bulk Salinity              | 7.46 ± 0.57 | 5.18 ± 0.34 | 6.61 ± 0.41 | 8.00 ± 0.57 |
| Brine Density (g cm⁻³)     | 1.04 ± 0.01 | 1.04 ± 0.01 | 1.04 ± 0.01 | 1.04 ± 0.01 |
| Brine Salinity             | 45.63 ± 6.09 | 48.07 ± 4.59 | 50.09 ± 5.94 | 53.23 ± 6.27 |
| Brine Volume (%)           | 14.16 ± 2.44 | 9.19 ± 0.87 | 11.31 ± 1.54 | 12.91 ± 2.34 |
| Air Volume (%)             | 1.57 ± 0.25 | 0.94 ± 0.09 | 1.24 ± 0.16 | 1.49 ± 0.25 |
| Chl a (mg m⁻²)             | 0.045 ± 0.01 | 0.033 ± 0.07 | 0.015 ± 0.004 | 0.022 ± 0.07 |
| $\Phi_{PSII\text{-}max}$   | 0.31 ± 0.11 | 0.26 ± 0.07 | 0.23 ± 0.08 | 0.24 ± 0.10 |
| $\alpha$ (mol e mol⁻¹ photons) | 0.14 ± 0.04 | 0.16 ± 0.04 | 0.08 ± 0.01 | 0.15 ± 0.07 |
| $rETR_{max}$ (μmol m⁻² s⁻¹) | 6.21 ± 3.77 | 4.74 ± 2.80 | 3.79 ± 3.73 | 2.00 ± 0.98 |
| $E_k$ (μmol photon m⁻² s⁻¹) | 41.51 ± 19.76 | 39.04 ± 29.56 | 43.22 ± 31.80 | 13.90 ± 3.63 |

3.2. ANOVA Analyses

Results of ANOVA analyses comparing within-core and between-core variation are shown in Table 3 for all measured parameters.

Table 3. One-way ANOVA analysis of physical and biological parameters from the 9 sea ice cores, comparing within-core and between-core variation. Within-core variation is comparison between the 4 core section heights (n = 9 replicate cores); between-core variation is comparison between the 9 cores (n = 4 core sections as replicates). Significant differences (p < 0.05) shown in **bold**.

| Parameter                  | Df * | MS  | F      | p    |
|----------------------------|------|-----|--------|------|
| Within-Core Variation      |      |     |        |      |
| Temperature (°C)           | 3, 32| 0.335 | 2.81 | 0.055 |
| Bulk salinity              | 3, 32| 13.61 | 58.48 | <0.001 |
| Brine salinity (g cm⁻³)    | 3, 32| 93.27 | 2.81 | 0.055 |
| Brine volume (%)           | 3, 32| 41.52 | 11.41 | <0.001 |
| Air volume (%)             | 3, 32| 0.72  | 18.52 | <0.001 |
| Chl a (mg m⁻²)             | 3, 32| 0.403 | 31.5  | <0.001 |
| $\Phi_{PSII\text{-}max}$   | 3, 23| 0.025 | 0.924 | 0.455 |
| $\alpha$ (mol e mol⁻¹ photons) | 3, 23| 0.317 | 2.87  | 0.003 |
| $rETR_{max}$ (μmol m⁻² s⁻¹) | 3, 23| 0.101 | 6.05  | 0.059 |
| $E_k$ (μmol photon m⁻² s⁻¹) | 3, 23| 0.258 | 2.54  | 0.082 |

| Between-core variation     |      |     |        |      |
|----------------------------|      |     |        |      |
| Temperature (°C)           | 8, 27| 0.419 | 7.73  | <0.001 |
| Bulk salinity              | 8, 27| 0.179 | 0.103 | 0.999 |
| Brine salinity (g cm⁻³)    | 8, 27| 116.74 | 7.74  | <0.001 |
| Brine volume (%)           | 8, 27| 8.77  | 1.39  | 0.247 |
Apart from temperature and the derived brine salinity, there were no parameters that showed significant between-core variation. Within-core variation was greater than between-core variation for all those parameters showing significant differences.

Table 3 shows that there were significant within-core variations in bulk salinity, and accordingly also in brine volume and air volume, as bulk salinity is a variable in deriving brine and air volumes [27]. There was a clear difference in Chl $a$ between the 0.045 ± 0.01 mg m$^{-2}$ in the bottom $x_1$ segment and the lower average concentrations in the top $x_4$ section of 0.022 ± 0.007 mg m$^{-2}$, and differences were highly significant (Table 3). Figure 3 shows the Chl $a$ concentrations and temperature for each segment in each of the nine cores.

![Figure 3. Chl $a$ (a) and (b) temperature in each of the segments of the nine cores. Blue is $x_1$, orange $x_2$, grey $x_3$, and yellow $x_4$.](image-url)
There were, in contrast, no significant within-core variations at \( p < 0.05 \) in temperature and most photobiological parameters (\( \Phi_{PSII_{max}}, rETR_{max}, \) and \( E_{K} \)). However, differences in \( \alpha \) were highly significant (\( p < 0.003 \)), and both \( rETR_{max} \) and \( E_{K} \) differed significantly at the \( p < 0.01 \) level (Table 3). The average sea ice temperatures varied between \(-2.58 \pm 0.36 ^\circ C\) in the bottom segment \( x_1 \) and \(-3.04 \pm 0.38 ^\circ C\) in surface segment \( x_4 \) with this temperature decrease observed in nearly all nine cores shown in Figure 3, but within-core variations were not significant. The between-core variations in temperature were significant where cores 6, 7 and 8 were about 0.5 °C colder compared to the other cores in Figure 3. The between-core variation in brine salinity was accordingly statistically significant, as brine salinity is the single variable in the direct inverse relation between temperature and salinity [27].

Post hoc analyses unraveled the within-core variations in average gas volume, bulk salinity, brine volume, Chl \( a \), and \( \alpha \) following the ANOVA analyses in Table 3. Brine volume in segment \( x_1 \) (b) was significantly different from segments \( x_2 \) (a) and \( x_3 \) (a) but not from segment \( x_4 \) (b), and no significant differences between \( x_2 \) (a) and \( x_3 \) (a) as seen in Figure 4.

![Figure 4. Average ± SD for gas volume, bulk salinity, brine volume (a), and Chl \( a \) and \( \alpha \) (b) for each segment \( x_1, x_2, x_3, \) and \( x_4 \). Post hoc Tukey comparisons for those parameters differing significantly according to ANOVA (\( p < 0.05 \), Table 3) are shown as different letter codes adjacent to the bars. Different letter codes (a, b, c) for a parameter in segments \( x_1, x_2, x_3, \) and \( x_4, \) show that values are significantly different, and similar letter codes that there are no differences.](image)

### 3.3. Power Analysis

Figure 5 presents models of replication required for detecting significant effects for different sea ice parameters based on the Kapisillit data of the present study. The large differences in bulk density and Chl \( a \) within cores give a greater effect size and hence less required replication than the photobiological parameters that differed less. In order to achieve significance at \( p < 0.05 \) with sufficient power to balance Type I and Type II errors, the analysis suggests a minimum of \( n = 4 \) and preferably \( n = 5 \) replicate cores to detect the observed variability in this sea ice.
to the origin at $n = 1$, as by definition there is zero power with only one replicate.

4. Discussion

4.1. Kapisillit Data in Comparison

This study showed significant variations in bulk salinity within-cores and derived brine and gas volumes. Temperature with derived brine salinity showed significant variations between cores, and Chl $a$ variations were also statistically significant within cores. Notably, all these parameters differed much more within cores than between cores in this sampling event, revealing relatively low spatial variation at the decimeter scale compared to the much larger vertical variation within cores.

There were, by contrast, no statistically significant variations in most photobiological parameters, with the exception of $\Phi$, either within-cores or between-cores. The present Chl $a$ concentrations ($<0.045$ mg m$^{-2}$) are somewhat lower than those found at other south-west Greenland sea ice locations such as Kangerlussuaq [4,22] and in Kobbefjord near Nuuk [26]. Compared to an Alaskan sea ice study the present $\Phi$ values are slightly lower, although that study encompasses three sampling locations within 4–5 km distance and four sampling dates [19]. The present $\Phi$ values were also clearly lower compared to a time-series study of the effects of increased irradiance in Kangerlussuaq [4], and both rETR$_{max}$ and $E_k$ were also comparatively lower at Kapisillit. These differences are likely a consequence of the light history experienced by the algae, with the low values at Kapisillit consistent with an early-season pre-bloom community of low activity [32].

4.2. Variability

Temperatures at the bottom of the ice cores were generally higher than temperatures in upper sections of the core, where sea ice temperatures are driven by external air temperatures and regulated by snow cover thickness [27]. The insulating effects of the present snow thickness of 17 cm is the probable explanation for the relatively high sea ice temperatures in the top segment ($-3.04 \pm 0.38 ^\circ C$) compared to the bottom segment ($-2.58 \pm 0.36 ^\circ C$), and also the explanation of no significant within-core variation—a variation that would

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**Figure 5.** Power analysis models for required replication ($n$) to achieve sufficient power for detection of statistical significance for sea ice parameters based on Kapisillit data in the present study. Models are based on a standard a priori required power level of 0.8 at $p < 0.05$. The vertical dashed lines at $n = 4$ and $n = 5$ delineate the range where sufficient power has been achieved for all studied parameters. Note that the formula applied to calculate power are unable to do so at $n = 1$ where there is no mathematical solution to them. To resolve this we have therefore extrapolated the lines to the origin at $n = 1$. 


probably have been significant without snow cover and lower top segment temperatures. Bulk salinity within-core variations were significantly different, which was also expected, as bulk salinity expresses a degree of desalination, whereby bottom segments generally show high bulk salinity due to infiltration of high saline ocean water [33], as also observed here. A study of the vertical variation in bulk salinity between cores taken 0.38 cm apart, similarly to the present study showed comparable low vertical salinity variations, also in first-year ice [34]. Brine volumes in the ice were relatively high and an increased permeability might have added to the variability by inflow of bottom sea water. Bulk salinity is a variable when deriving brine and air volumes, and they both showed statistically significant variations. This was also the case for Chl a, as Chl a is often highest at the bottom of the ice core where the ice algae are in direct contact with the nutrient-rich ocean water [4].

It is, in comparison, very interesting that there was no statistically significant within-core variation in three of the photobiological parameters: Φ_{PSII,max}, rETR_{max}, and E_k. Φ_{PSII,max} is an expression of the functionality of the algal photobiology, especially Photosystem II, and is related to the availability of nutrients and light history during growth [27,28], here in the sea ice brine channels. There are no data on nutrient concentrations in the present study, but nitrogen (0.5–1.5 µmol L\(^{-1}\)) as well as phosphate (0.1–0.2 µmol L\(^{-1}\)) were both low in a similar ice in late February near Nuuk [26], and with very low light in the ice core below the snow cover. Nutrient concentrations were relatively high in the under-ice water, demonstrated in a previous study [17] for an average spring (February, March, April, May) of NO\(_2^-\) + NO\(_3^-\) = 8.6 µmol L\(^{-1}\). This indicates that the ice algae were possibly in a resting stage just before increased light and spring bloom when snow starts melting [32]. A resting pre-spring bloom stage would also explain the low rETR_{max} values as well as the low Chl a in the cores. Transmittance at Kapisillit was low (0.01) and provided an under-ice PAR of 6.7 µmol photons m\(^{-2}\) s\(^{-1}\) at midday sampling time, which is significantly lower compared to under-ice PAR in Kangerlussuaq of 100–150 µmol photons m\(^{-2}\) s\(^{-1}\) [4]. A threshold value as low as 0.17 µmol photons m\(^{-2}\) s\(^{-1}\) for algae growth has been observed in a recent study [35], so even with a PAR of 6.7 µmol photons m\(^{-2}\) s\(^{-1}\) it appears that algae were in a resting stage. This is also supported by previous observations [19] where a general increase in rETR_{max}, α, and Φ_{PSII,max} in sea ice between winter and spring supports the interpretation of a resting stage. There were no statistically significant within-core variations in Φ_{PSII,max}, which compares to a similar low vertical variation of Φ_{PSII,max} [19].

One of the goals of this study was to explore the degree of replication needed in sea ice to characterize physical and biological parameters at <1 m scales in future studies. Applying the present data as a pilot study for future sampling of first-year landfast sea ice, the power analyses carried out here suggest replication levels of \(n = 4\) to 5 replicates per sampling location as generally sufficient to capture significant differences for Chl a, rETRmax, and α.

5. Conclusions

This investigation of small-scale horizontal and vertical comparison of within-core and between-core variation has revealed that the horizontal (between cores) variability is too small to obscure the statistically significant vertical gradients in physical-chemical and biological parameters commonly observed in this type of first-year land-fast sea ice. Temperature was a key parameter being related to the physical parameters. While patchiness of ice algal biomass and photobiological properties are always a concern in sea ice biology, this study suggests that sampling sizes of 4–5 cores per sampling site (e.g., comparison of sites, seasonal studies, etc.) should be sufficient to detect statistically significant differences that are meaningful for sea ice ecology. It is emphasized that present results, based on limited data, are restricted to first-year sea ice in late winter and more studies are required to reveal the seasonal signal and variations relative to temperature and snow cover.
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