Spatial and temporal variability of the physical and biogeochemical properties of Antarctic sea ice from sea ice records

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Introduction

Antarctic sea ice acts as an **interface** between ocean and atmosphere. Its composition and extent is **seasonal**, with highly variable features. Spatial and temporal variation of sea ice and the physical and biogeochemical properties that follow are related to oceanic and atmospheric variability. The influence of variations is **understudied** due to limitations and complications involved with in situ research.

Aims

1. Consolidate all biogeochemical and physical properties from data collected during South African expeditions and historical data from expeditions dating back to 1981.
2. Variability across space and time was assessed using exploratory and multivariate analysis (PRIMER-e).

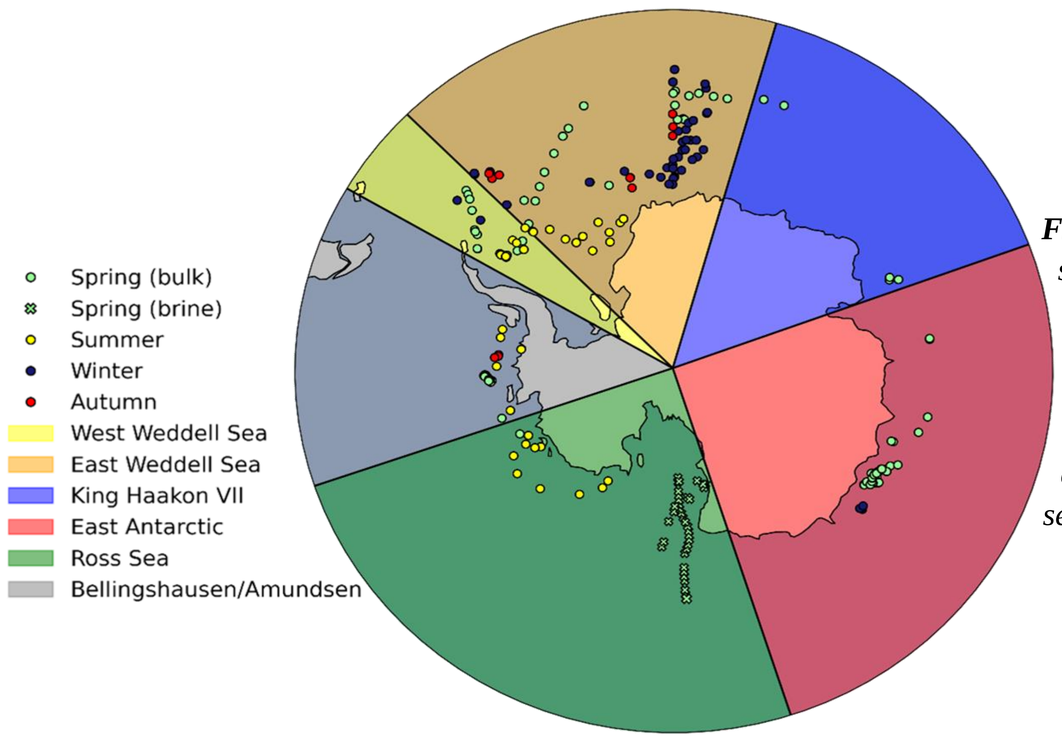

Figure 1. *Distribution of sea ice cores collected across the Antarctic regions during the period of 1981 and 2019. The cores are coloured according to season. Modified sectors are indicated.*

Results and Discussion

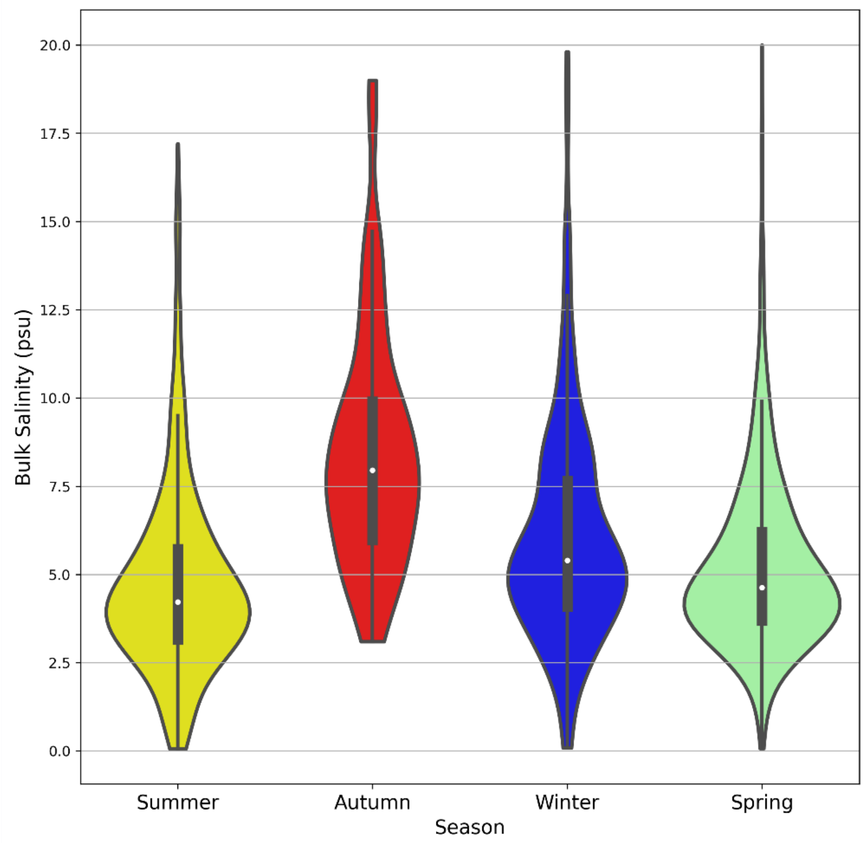

Figure 2. *Violin plots with embedded box plots showing the distribution of sea ice salinity across the different seasons in the Antarctic region.*

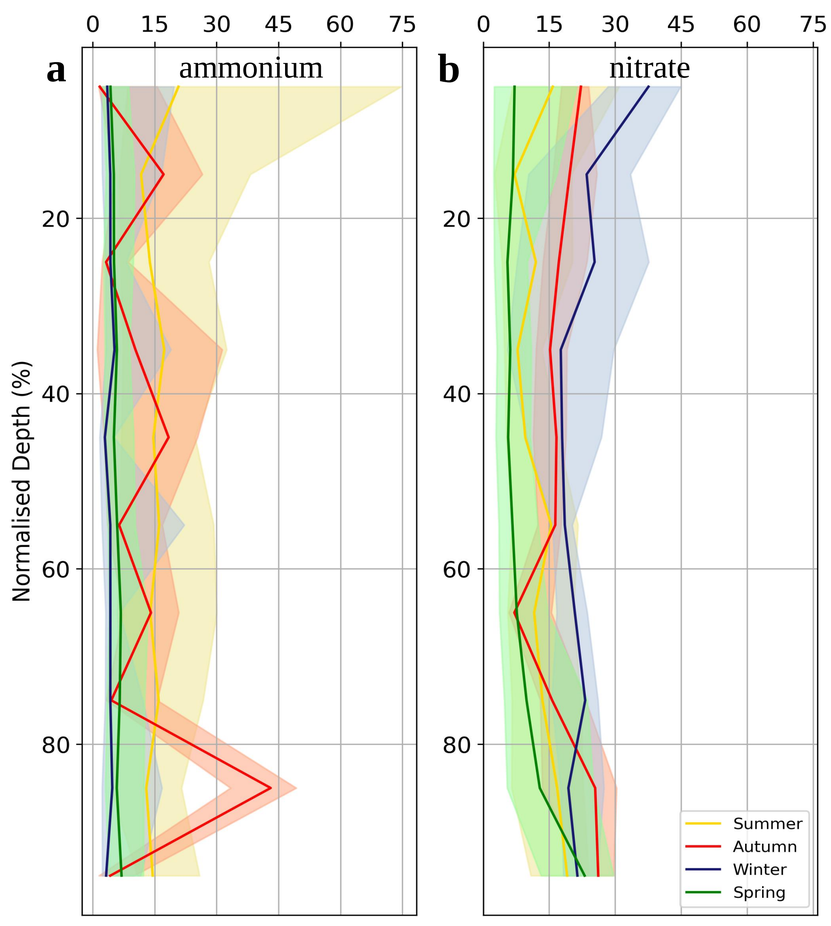

Figure 3. *Vertical profiles for (a) ammonium and (b) nitrate (µmol/L) for the Antarctic region. The median is the solid line and shaded area the interquartile range (IQR) for each season.*

- There were 316 cores in total across 23 expeditions (figure 1), the East Weddell Sea is the most represented (50,6%), with King Haakon VII Sea (15) and Ross Sea (16) having the least samples.
- Spring is the most represented season (48,1%) and autumn is the least (6,0%).
- The expected thickening from autumn to summer is seen.
- For season and region the bulk salinity is between 5-8 which is expected for Antarctica. There is a shift upward of median and interquartile range for autumn (figure 2). King Haakon VII Sea shows the lowest median and range for salinity < 5.
- Ammonium concentrations are within the range for bulk sea ice, summer has a large IQR in the top section and autumn shows a peak in the bottom section (figure 3 a). For nitrate, the seasons are within the concentration range, but winter is slightly greater at the surface (figure 3 b).

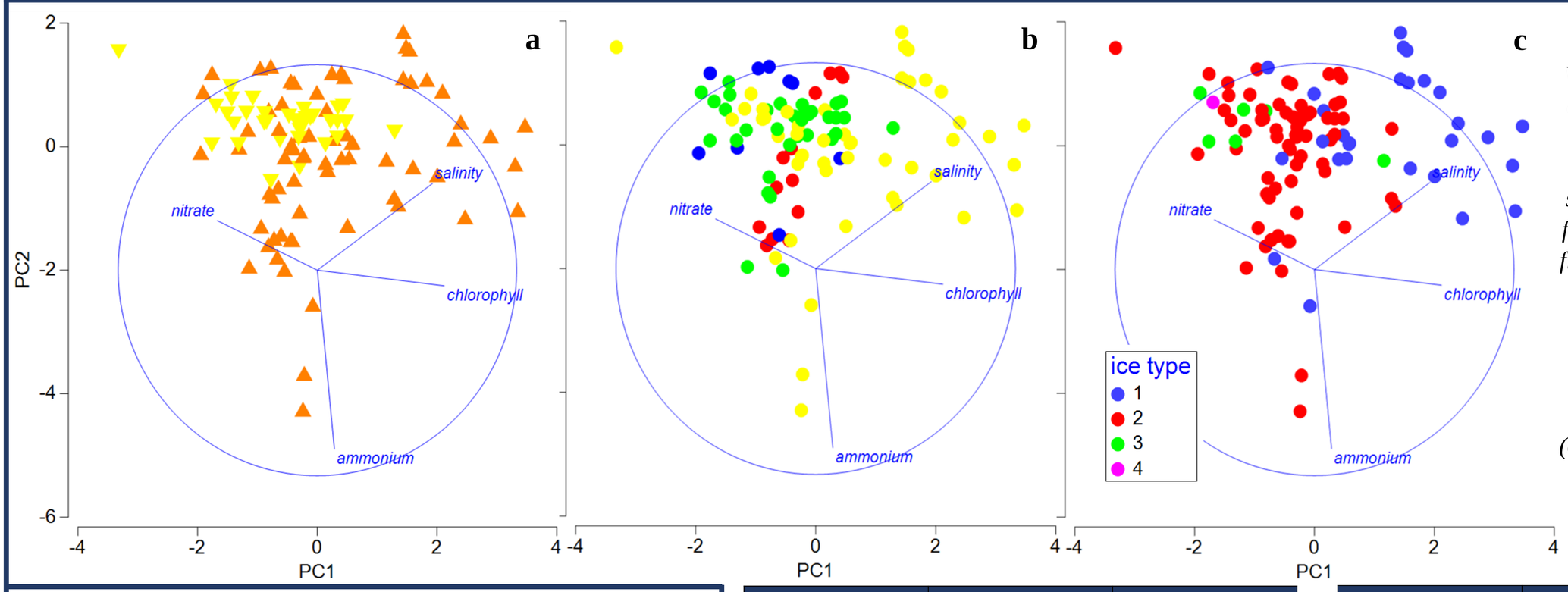

Figure 4. *PCA plots for the Weddell Sea region using reduced dataset with salinity, chlorophyll, nitrate and ammonium as the variables, with (a) region, (b) season and (c) ice type defined as factors. The colours correspond to figure 1. Ice type is used to classify stages of development (i.e. first-year, multi-year ice). Most variation is captured by PC1 (37,5%) mainly along the chlorophyll (0,637) and salinity (0,577) components. PC2 accounts for 27,4% of variation, mainly captured by the ammonium (-0,871) component.*

(a) West Weddell Sea group together, although the samples overlap with the East Weddell Sea. No distinct clustering seen for season (b), summer has a wider spread compared to the tight grouping of autumn, spring and winter. (c) Ice type appears to have different spreads, although there is overlap the different types appear to group more tightly together.

Factor	R-value	P-value
(a) Region	-0,009	0,518
(b) Season	0,005	0,417
(c) Ice type	0,4	0,001

Table 1.

ANOSIM values indicate moderate to strong levels of separation for ice type and are statistically different and distinct. No meaningful differences for region and season.

Factor	Pseudo F-stat	P-value
(a) Region	1,5802	0,1856
(b) Season	2,2778	0,0230
(c) Ice type	2,3087	0,0428

Table 2.

PERMANOVA values show season and ice type significantly influence variability. Region values indicate no significant difference between the regions.

In conclusion there were no clear patterns, with the multivariate analysis indicating that variability is best assessed according to ice type rather than by season or region.

(1) Thomas, D & Dieckmann, G. (2002). Biogeochemistry of Antarctic Sea Ice. Oceanography and marine biology. 40. 143-169. 10.1201/9780203180594.ch3.
(2) Fripiat, F, et al 2017 Macro-nutrient concentrations in Antarctic pack ice: Overall patterns and overlooked processes. Elem Sci Anth, 5: 13, DOI: https://doi.org/10.1525/elementa.217
(3) Skatulla, S., et al., Physical and mechanical properties of winter first-year ice in the Antarctic marginal ice zone along the Good Hope Line, The Cryosphere, 16, 2899–2925, https://doi.org/10.5194/tc-16-2899-2022 , 2022.
(4) Audh, R. R., (2023). Rafting of growing Antarctic sea ice enhances in-ice biogeochemical activity in winter. *Journal of Geophysical Research: Oceans*, *128*, e2023JC019925. https://doi.org/10.1029/2023JC019925

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