A database of marine macronutrient, temperature and salinity measurements made around the highly productive island of South Georgia, the Scotia Sea and the Antarctic Peninsula between 1980 – 2009

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Abstract. We present a database from substantial collections of macronutrient data made on 20 oceanographic cruises, primarily from around the island of South Georgia and the Scotia Sea. This sector of the Southern Ocean was studied comprehensively during the Discovery Investigations between ~1920 and 1950 and resulted in the hugely influential Discovery Reports. Following this pioneering research period, there was a lull of several decades prior to the British Antarctic Survey's

15   (BAS) initiation of an offshore biological programme to study the ecology of the South Atlantic sector of the Southern Ocean. These studies began in the late 1970s and have continued until the present day. Between 1980-2009, the programme included macronutrient measurements as part of an integrated ecosystem analysis. In addition to South Georgia and the Scotia Sea, measurements were also made in the Bellingshausen Sea and the waters to the west of the Antarctic Peninsula. Data were collected during all months of the year with the exceptions of May and June and compiled into a database. Vertical profile

20   samples were taken from water bottles while data along transects were collected through monitoring the ship's non-toxic seawater supply. Nutrients measured were silicate, $Si(OH)_4$-Si; phosphate, PO_4-P; nitrate, NO_3-N; ammonium NH_4-N; and nitrite, NO_2-N. Our database includes nutrient data along with contemporaneous temperature and salinity data where available. Further background and supporting information are included for context.

1 Introduction

25   ### 1.1 Geography and physical oceanography

The island of South Georgia lies on the Scotia Ridge, a submarine arc in the southwest Atlantic sector of the Southern Ocean that extends eastwards from South America to the South Sandwich Islands, returning westwards to the Antarctic Peninsula. The arc forms the northern, eastern and southern boundary of the Scotia Sea with Drake Passage forming the western boundary.

South Georgia and its broad continental shelf lie within the Antarctic Zone (AAZ) of the predominantly eastward flowing Antarctic Circumpolar Current (ACC). The AAZ is bounded by the Polar Front (PF) to the north and the Southern Antarctic Circumpolar Current Front (SACCF) to the south (see Fig. 1; Nowlin and Klinck, 1986; Orsi et al., 1995). In the Scotia Sea, the ACC is deflected northeastward by the local bathymetry. The SACCF approaches South Georgia from the southwest and is inflected around the eastern and northern continental shelf of the island before retroflecting eastwards at the Northwest Georgia Rise (Orsi et al., 1995; Thorpe et al., 2002; Meredith et al., 2003; Boehme et al., 2008). The oceanic circulation at South Georgia has been studied with Eulerian and Lagrangian observations, and modelled at increasingly higher resolutions. These studies demonstrate a northwestward flow along the island's northern shelf edge, cross-shelf exchange and areas of retention on the island's continental shelf (Hardy and Gunther, 1935; Maslennikov, 1979; Priddle et al., 1986; Latogursky et al., 1990; Trathan et al., 1997; Brandon et al., 1999, 2000; Young et al., 2014). Recent fine-scale ocean models not only reconstruct the larger-scale circulation features but also resolve eddy-scale processes, and suggest the existence of coastal upwelling jet structures that have yet to be physically observed (Young et al., 2011, 2014; Matano et al., 2020).

The long-term mean positions of the ACC fronts mask the degree of large- and mesoscale variability. Meandering and eddy shedding have been described for ACC fronts (e.g. Lutjeharms and Baker, 1980; Bryden, 1983). In areas of irregular bottom topography such as the northeastern Scotia Sea, the fronts are particularly variable (e.g. Gordon et al., 1977; Peterson and Whitworth, 1989; Boehme et al., 2008). The positions of fronts and eddies influence the waters and plankton communities around South Georgia. There is some evidence, for example, that warm water eddies of Polar Frontal Zone origin (i.e. from north of the PF) influence the South Georgia region from the west (Atkinson et al., 1990; Whitehouse et al., 1996b).

1.2 Research history

South Georgia has been commercially exploited for centuries from the sealing of the late 1700s (Bonner, 1984; Headland, 1984) to the whaling industry in the early 20th century (Harmer, 1931; Kemp and Bennett, 1932) and the current krill fishery in the Southern Ocean (Everson and Goss, 1991; Trathan et al., 1998).

The Discovery Investigations were initiated in the 1920s to provide an ecosystem approach to managing whaling. Multi-ship surveys were undertaken to understand the causes of the region's high primary productivity and how it supported the fisheries. The resulting Discovery Reports covered many topics from oceanography to whales, and the report on the plankton by Hardy and Gunther (1935) linked the environment and higher trophic levels using some very modern concepts. For example, they suspected that micronutrients controlled phytoplankton productivity. Later Discovery Investigations broadened their coverage to include South Georgia as part of the Scotia Sea-Antarctic Circumpolar Current system (e.g. Foxton, 1956; Marr, 1962; Mackintosh, 1973).

The Discovery Investigations laid the foundations for our understanding of phytoplankton growth and nutrient use at South Georgia. Hardy and Gunther (1935) and Hardy (1967) correlated locally reduced phosphate concentrations with elevated phytoplankton biomass, suggesting that phosphate depletion provided a time-integrated "memory" of primary production.

65 Clowes (1938) showed summer silicate and phosphate reductions, and possible year-to-year variation in phytoplankton utilisation, and suggested that silicate concentrations may, in some years, limit phytoplankton growth. A wider scale context was provided by Hart (1934, 1942) who noted the general failure of Antarctic marine phytoplankton to deplete fully the abundant pools of macronutrients in the surface waters: now known as the High-Nutrient-Low-Chlorophyll paradox (HNLC).

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Between 1940 and 1970, much less scientific work was undertaken in the vicinity of South Georgia. However, from the late 1970s to the present-day, attention has been renewed with work being undertaken by the British Antarctic Survey (BAS). Altogether, offshore, ecological studies have been conducted sporadically around South Georgia and in the Scotia Sea for about a century.

75 **1.3 Phytoplankton productivity and nutrient controls**

The AAZ's open ocean is generally considered to be a zone of low productivity. However, the South Georgia region is characterised by high biomass and productivity of phytoplankton, zooplankton and vertebrate predators.

Although the AAZ is characterised by HNLC conditions (maximum chlorophyll a ~1 mg m^{-3}), parts of the Scotia Sea may be
80 more productive (but still usually <2.5 mg chlorophyll a m^{-3}, Rönner et al., 1983; Jacques, 1989; Tréguer and Jacques, 1992; Korb et al., 2005). However, during a series of cruises across the Scotia Sea, concentrations of chlorophyll a >3 mg m^{-3} were found at ~58°S in spring (Korb et al., 2012). Phytoplankton blooms >0.75 mg m^{-3} chlorophyll a persisted for >6 months during the 2006/2007 season in this mid-Scotia Sea zone. Similarly, a large-scale bloom investigated during the 2011/2012 season downstream of South Georgia revealed chlorophyll a concentrations of >3 mg m^{-3}, peaking in December, with the bloom
85 persisting (chlorophyll a > 0.5 mg m^{-3}) until mid-March. Furthermore, in comparison to those in the open ocean, the South Georgia bloom was characterised by higher chlorophyll a-specific carbon fixation, indicative of high photosynthetic efficiency (Hoppe et al., 2017).

With decades of both field observations and remotely sensed ocean colour data available to investigate spatial and temporal
90 variability, there is clear evidence that phytoplankton blooms are more frequent and more intense downstream of South Georgia and into the Georgia Basin relative to upstream (e.g. Borrione and Schlitzer; 2013). High phytoplankton concentrations (>20 mg chlorophyll a m^{-3}) may be linked to enhanced supplies of iron (up to 4 nmol m^{-3}, de Baar et al., 1995; Whitehouse et al., 2000; Korb et al., 2004; Nielsdottir et al., 2012; Schlosser et al., 2018) or reduced forms of nitrogen (up to 3 mmol ammonium m^{-3}, Owens et al., 1991; Priddle et al., 1997; Whitehouse et al., 1999). Although macronutrients are generally non-limiting in

95 the AAZ, silicate concentrations limit growth (<1 mmol m^{-3}) at South Georgia in some summers (Whitehouse et al., 1996a, 2008). During trans-Scotia Sea cruises from ~61-50°S, substantial latitudinal gradients were found for silicate, nitrate and phosphate (Whitehouse et al., 2012). Surface ammonium concentrations were substantially higher to the north of the North Scotia Ridge although a peak in values was measured around the southern boundary of the ACC, coincident with increased mid-Scotia Sea chlorophyll *a* concentrations. These transects crossed multiple oceanographic features that may each contribute

100 to increased productivity and nutrient depletion. However, silicate was the only macronutrient to be found at limiting concentrations and only north of 56°S (Whitehouse et al., 2012).

Observations, together with coupled hydrodynamic and biogeochemical models, support a strong supply of iron downstream of South Georgia, sourced from shallow shelf sediments (<20 m water depth), glacial meltwaters and particulates, upwelling

105 deep waters transported by the ACC and topographic steering, and a lesser contribution from dust (Nielsdottir et al., 2012; Borrione et al., 2014; Hoppe et al., 2017; Schlosser et al., 2018; Matano et al., 2020). The alleviation of iron limitation not only drives the bloom initiation, but also has the potential to shift the uptake ratio of macronutrients, impacting regional stoichiometry (Borrione et al., 2014; Hoppe et al., 2017). However, the lateral advection of iron alone cannot explain the variability in duration of downstream blooms near South Georgia (Robinson et al., 2016). Mixed-layer depths and

110 phytoplankton-zooplankton interactions will also likely play a role in nutrient stoichiometry; grazing pressure plays an important role in bloom dynamics and rapid, shallow nutrient cycling and effectively traps nutrients in the surface mixed layers of the downstream waters (Robinson et al., 2016; Schlosser et al., 2018; Cavan et al., 2019).

Although there is intensive recycling in the surface mixed layer, the high summer primary productivity to the north of South

115 Georgia is reflected in organic carbon export and inorganic carbon uptake. For example, in austral summer 2012, the flux of particulate organic carbon (POC) collected in sediment traps downstream and upstream of South Georgia (1500-2000 m water depth) were 46-904 and 38-205 µmol m^{-2} d^{-1} respectively (Rembauville et al., 2016). That study also found downstream export to have a relatively low Si:C ratio, due to a lower proportion of empty diatom frustules, with over 40% of the sinking POC associated with diatom resting spores. The extensive summer blooms around South Georgia also deplete dissolved inorganic

120 carbon (DIC), acting as a strong sink for atmospheric CO$_2$, although this is countered in the winter due to strong mixing (Jones et al., 2012).

Despite some retention over the continental shelf of South Georgia, the high productivity of phytoplankton is widespread extending into deep waters to the north of the island and to the PF (>8 mg chlorophyll *a* m^{-3}, Fryxell et al., 1979; El-Sayed and

125 Weber, 1982; Whitehouse et al., 1996b, 2000; Korb et al., 2004, 2008; Korb and Whitehouse, 2004; Hoppe et al., 2017). Such high productivity can also be sustained for thousands of kilometres downstream (Korb et al., 2004), in part due to the supply of nutrients by meandering mesoscale structures that form during interactions between the oceanic fronts and topographic features (Smith et al., 2010; Jones et al., 2017). Indeed, the large spatial extent and long growth season (Korb et al., 2004;

Hoppe et al., 2017) mean that the South Georgia blooms are associated with the strongest predicted carbon sink in the Southern
130 Ocean (Schlitzer, 2002).

In this paper we present a multi-year nutrient dataset along with concurrent temperature and salinity measurements. We detail
methods, consider preliminary data evaluation, and summarise previous data management and utilisation. In addition to data
availability, we consider their potential use and also catalogue supporting cruise report information.

135 **2 Methods**

The present macronutrient database has been collated from direct measurements made by BAS scientists (principally MJW)
as part of sampling campaigns conducted from scientific research vessels to the respective regions of the Southern Ocean.
Samples were collected via two principle collection methods: CTD water bottles or the underway non-toxic ship's seawater
supply. Initial measurements were made at sea and concentrations calculated post-cruise. These data were initially published
140 in a number of different sources which have been compiled as part of the present exercise (see Whitehouse et al., 2022).
Furthermore, we have carried out additional quality control of these measurements and added supplementary data fields to the
database that we are now making externally accessible (Whitehouse et al., 2022).

2.1 Sampling sites

The current dataset was collected between 1980 and 2009 (Table 1).

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Table 1. Cruise, duration, region and nutrients measured at CTD stations (●) and during transects (●). *MEB - Maurice Ewing Bank transect between 48°S, 44°W and 54°S, 39°W. Concurrent temperature and salinity values are presented for all CTD profiles and for cruises JR161, JR177 and JR200 transect measurements.

Cruise	From	To	Region	Si(OH)₄-Si	PO₄-P	NO₃-N	NH₄-N	NO₂-N
JB03	Nov-81	Jan-82	South Georgia	●	●	●		
JB04	Jul-83	Oct-83	South Georgia	●	●	●		●
JB05	Jan-85	Feb-85	Bransfield Strait	●	●	●	●	●
JB06	Dec-85	Jan-86	South Georgia	●	●	●	●	●
JB08	Jan-88	Mar-88	South Georgia/Bransfield Strait	●	●	●	●	●
JB10	Jan-90	Feb-90	South Georgia	●	●	●	●	
JR02	Nov-92	Dec-92	Bellingshausen Sea	●	●	●	●	●
JR06	Jan-94	Feb-94	South Georgia inc. MEB*	●	●	●	●	●
JR11	Jan-96	Jan-96	South Georgia inc. MEB*	●	●	●	●	●
JR17	Dec-96	Jan-97	South Georgia inc. MEB*	● ●	● ●	● ●	● ●	● ●
JR25	Oct-97	Nov-97	South Georgia inc. MEB*	● ●	● ●	● ●	● ●	● ●
JR28	Jan-98	Feb-98	South Georgia	● ●	● ●	● ●	● ●	● ●

JR38	Dec-98	Jan-99	South Georgia	● ●	● ●	● ●	● ●	● ●
JR57	Dec-00	Jan-01	South Georgia	● ●	● ●	● ●	● ●	● ●
JR70	Jan-02	Feb-02	South Georgia	● ●	● ●	● ●	● ●	● ●
JR82	Jan-03	Feb-03	Scotia Sea and South Georgia	● ●	● ●	● ●	● ●	● ●
JR116	Dec-04	Jan-05	South Georgia	●	●	●	●	
JR161	Oct-06	Nov-06	Scotia Sea and South Georgia	● ●	● ●	● ●	● ●	
JR177	Jan-08	Feb-08	Scotia Sea and South Georgia	● ●	● ●	● ●	● ●	
JR200	Mar-09	Apr-09	Scotia Sea and South Georgia	● ●	● ●	● ●	● ●	

150 Measurements were made predominantly around the island of South Georgia and across the wider Scotia Sea with additional sampling to the west of the Antarctic Peninsula and in the Bellingshausen Sea (Fig. 1a and 1b).

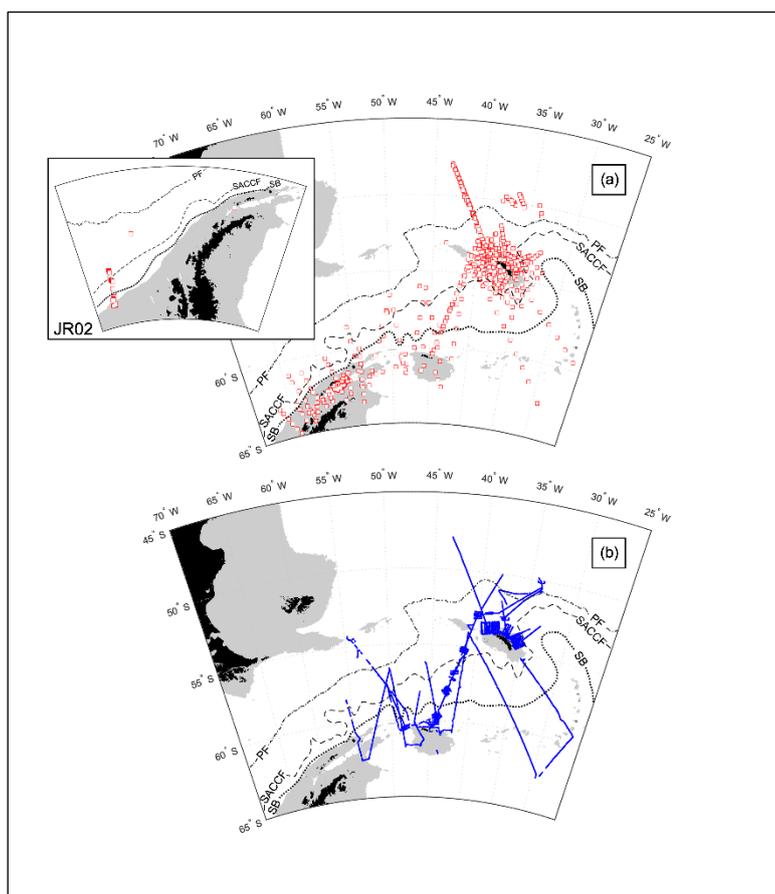
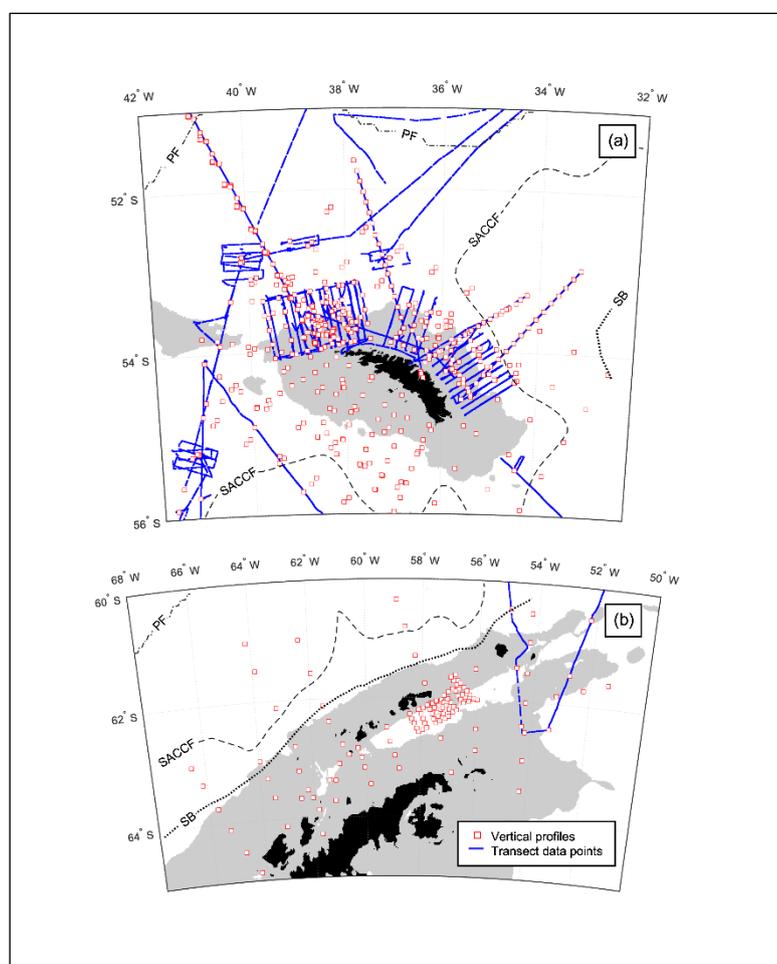



Figure 1. Sample locations of (a) CTD vertical profiles with inset to show stations sampled in the Bellingshausen Sea during cruise
155 **JR02; (b) transect data points. Southern Ocean fronts are shown in each panel: PF, Polar Front; SACCF, Southern Antarctic Circumpolar Current Front; and SB, Southern Boundary of the Antarctic Circumpolar Current (Orsi et al., 1995; Moore et al.,**

1999; Thorpe et al., 2002; Orsi and Harris, 2019). Pale grey areas show water depths <1000 m (Amante and Eakins, 2009; NOAA National Geophysical Data Center 2009). Coastline following GSHHG, version 2.3.7.

160 During nearly 30 years of sampling, some sites were repeatedly visited. Two monitoring areas termed the Eastern Core Box (ECB) and the Western Core Box (WCB) to the north of South Georgia have been studied intensively with a set of repeat transects oriented across the northeastern and northwestern shelf break to sample on- and off-shelf waters (Fig. 2a).

165 **Figure 2. Smaller-scale detail of sampling around (a) South Georgia; (b) Antarctic Peninsula. Southern Ocean fronts, pale grey areas and coastline are as in Figure 1.**

A series of stations spanning >700 km from the western end of South Georgia to the northwest crossed the PF and a number of bathymetric features including the Maurice Ewing Bank (50.667°S, 43.5°W) after which the transect was named. Three

170 cruises crossed the Scotia Sea from south to north in consecutive years and covered spring, summer and autumn periods (see

Tarling et al., 2012). These cruises along with the Core Box surveys to the north of South Georgia included extensive underway sampling (see Section 2.2), while surveying near the Antarctic Peninsula comprised predominantly station grids (Fig. 2b).

2.2 Chemistry instrumentation and methods

175 In 1979, a segmented-flow analyser (SFA) was built in-house to analyse macronutrient measurements for the BAS offshore programme. It was based on Chemlab colorimeters and Ismatec proportioning pumps (Whitehouse and Woodley, 1987). Originally, data were logged to paper chart and processed manually. In the mid-80s, data extraction was automated and processing was managed with a digitising tablet and associated PC (Woodley, 1989).

During 1993, the analyser was completely remodelled around Technicon colorimeters, the Ismatec proportioning pumps were
180 updated, the chemistry manifolds were re-built and data were logged to a PC (Whitehouse, 1997). Data acquisition and subsequent processing was achieved with custom-built software (see Whitehouse and Preston, 1997).

All data were collected during BAS or other Natural Environment Research Council cruises aboard the RRS John Biscoe (cruises prefixed JB) or the RRS James Clark Ross (cruises prefixed JR). The macronutrients analysed are described fully in
185 Whitehouse and Woodley (1987). They agree with the internationally accepted conventions for silicic acid ($Si(OH)_4$–Si), orthophosphate (PO_4–P), nitrate (NO_3–N), nitrite (NO_2–N), and ammonium (NH_4–N). All concentrations are expressed as mmol m^{-3}. A statistical analysis of the chemistry methods was documented in Whitehouse and Woodley (1987) but we present a summary for this analysis in Table 2.

190 **Table 2. Replication and limits of detection measured for chemistry methods (Whitehouse and Woodley, 1987).**

	$Si(OH)_4$-Si	PO_4-P	NO_3-N	NH_4-N	NO_2-N
Replication (n)	9	20	12	9	12
Concentration (mmol m^{-3})	71	3.2	0.7	3.6	8.9
Standard deviation of replicates (% of mean)	0.14	0.47	0.75	0.42	0.8
Limit of detection (mmol m^{-3})	0.28	0.05	0.28	0.01	0.01

Data were collected by means of two sampling methods. First of all, sub-samples were taken from CTD (conductivity, temperature, depth) rosette water bottles that provide the conventional vertical profiles. Water samples were taken from CTD upcasts, in which bottles were fired at depths ranging from 0.5 m to 5500 m. Secondly, samples were analysed continuously
195 from the ship's non-toxic seawater supply while the vessel was underway to provide high-resolution horizontal coverage of near-surface conditions during transects. Here we document further details of the sample handling regime.

The ship's non-toxic seawater inlet was at ~6-7m and forward of the bows to avoid contamination. The time-lag between seawater entering the ship's non-toxic inlet and reaching the chemistry laboratory was ~60 seconds (S. Wright, Deck Engineer, pers. comm., 31 December 1996). On arrival at the chemistry laboratory, the stream of seawater passed through a tangential flow filter block (Morris et al., 1978) fitted with a filter membrane (pre-1990 Whatman GF/C, pore size 1.2 µm, and then a mixed ester Whatman WME, pore size 0.45 µm) (Fig. 3).

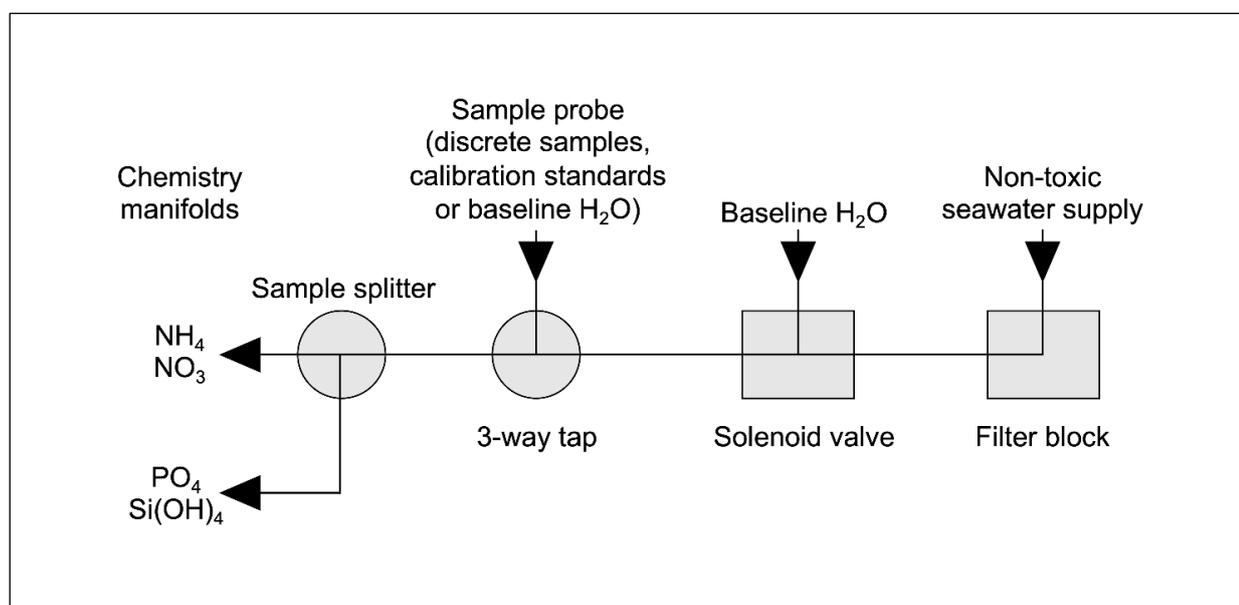



Figure 3. Sample handling schematic for flow of samples, standards and baseline blanks between ship's non-toxic seawater supply and the chemistry manifolds of the segmented-flow analyser.

A sub-sample was then pumped through a solenoid valve controlled with an electric timer. Typically, a 5 min baseline check was automatically introduced once per hour while the ship was underway and horizontal profiles were being measured. The sample stream then passed through a 3-way tap before arriving at a sample stream splitter followed by introduction to the chemistry manifolds. The 3-way tap allowed manual interruption of the sample stream to introduce discrete samples from the CTD water bottles along with calibration standards and blank solutions for the calculation of baselines, refractive index compensation and flow-through times.

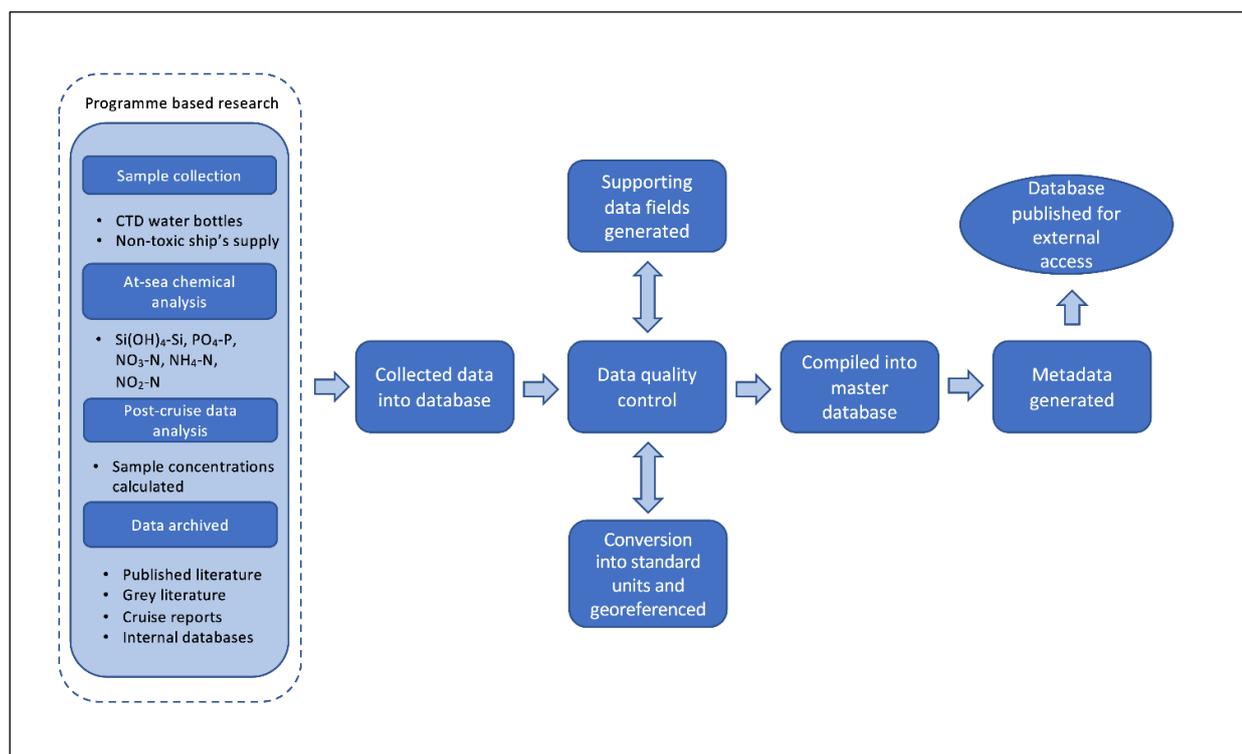
The time-lag between the sample entering the laboratory and passing through the analyser to the detector varied between the different nutrient analyses depending on the complexity of the chemistries used. Therefore, underway measurements were time and date stamped at the analyser's detector by referencing the ship's central clock to enable integration with navigation and other underway measurements such as physical oceanography and phytoplankton-related information (see Whitehouse and Preston, 1997). The underway data were originally logged at a 10 second interval. However, given the time-lag between

220   seawater entering the ship's non-toxic inlet and reaching the chemistry laboratory (~60 seconds), the detector's output was averaged over one-minute intervals during post-cruise processing to give a more realistic sampling sensitivity.

2.3 Temperature and conductivity measurements

Temperature and conductivity measurements were taken during CTD vertical profiles and with a thermosalinograph as part of the underway system that sampled from the ship's non-toxic seawater supply. During most cruises, the vertical profile
225   conductivity measurements were calibrated against samples drawn from the CTD water bottles. Temperature and salinity data from the profile upcast were averaged onto the depth and time of the bottle firing for most nutrient samples taken from the CTD water bottles but, where this was not possible, the downcast profile data were binned onto the depth (± 2 metres) of the nutrient sample. Further details are provided in the respective cruise reports (Appendix 1). For this dataset, the underway temperature and conductivity measurements have not been calibrated against sample measurements but were averaged over a
230   60 second interval to smooth the data.

2.4 Dataset compilation

The compilation of the dataset is summarised in Fig. 4.

235   **Figure 4. Flowchart of dataset compilation including sample collection, data processing and utilisation.**

CTD water bottle data were compiled with ship, ship identification information, cruise number, event number, geographic location and depth. Temperature and salinity data were extracted and matched with profile nutrient data from each cruise using latitude and depth as primary selector variables, with event numbers and timestamps used as secondary checks.

240

The non-toxic ship's seawater supply data were compiled with ship, ship identification information, cruise number, geographic location, temperature and salinity, and each timestamp reformatted as a date vector, a serial date number, and a datetime string (DD-MMM-YYYYThh:mm:ssZ). The serial date numbers were ordered temporally, converted into a datetime string (DD-MMM-YYYYThh:mm:ssZ), and converted to a table with minute intervals and corresponding arithmetic means of

245 concentrations of each nutrient, temperature and salinity.

The profile and underway sample data have been deposited at the UK Polar Data Centre and are publically available in the NetCDF and CSV formats as of the date of publication (Whitehouse et al., 2022).

250 All available cruise reports (17 in total) that provide cruise and individual projects as well as additional background information on the current dataset have been compiled (Appendix 1).

3. Results

3.1 Data evaluation

In all, ~10,000 CTD water bottles were sampled and analysed, and ~900,000 one-minute bins of data were recorded from the

255 underway sampling over the period 1980-2009. As with other high latitude marine sampling projects, logistics and ice conditions dictated when surveys could be conducted. January was the most frequent month of collection although sampling occurred in all months apart from May and June (Fig. 5).

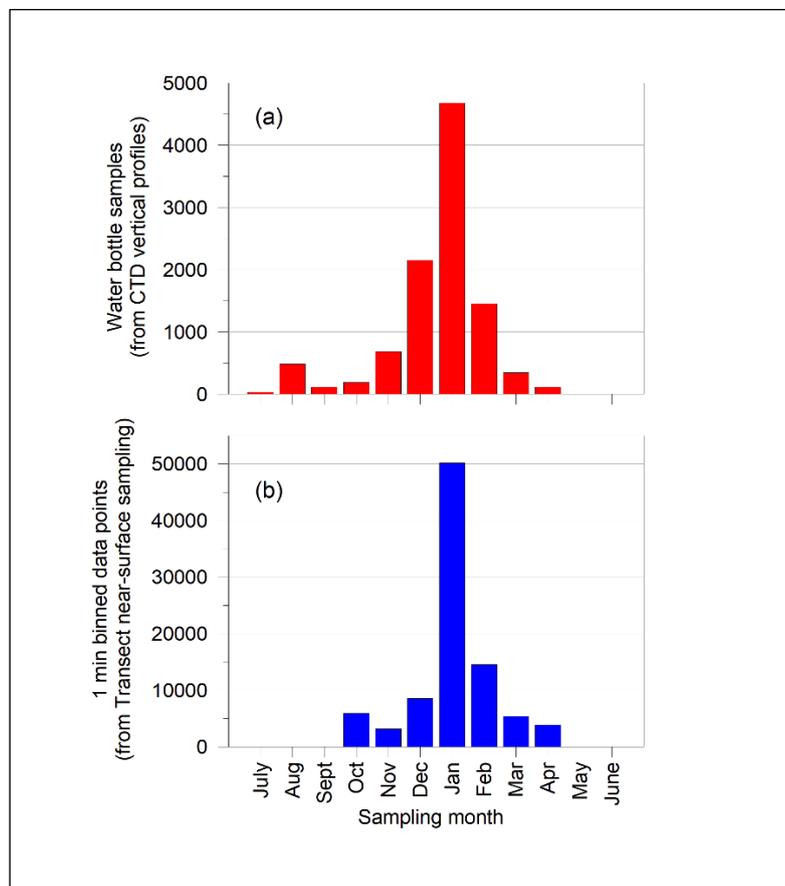



Figure 5. Monthly totals for nutrient samples from CTD water bottles and transect data points.

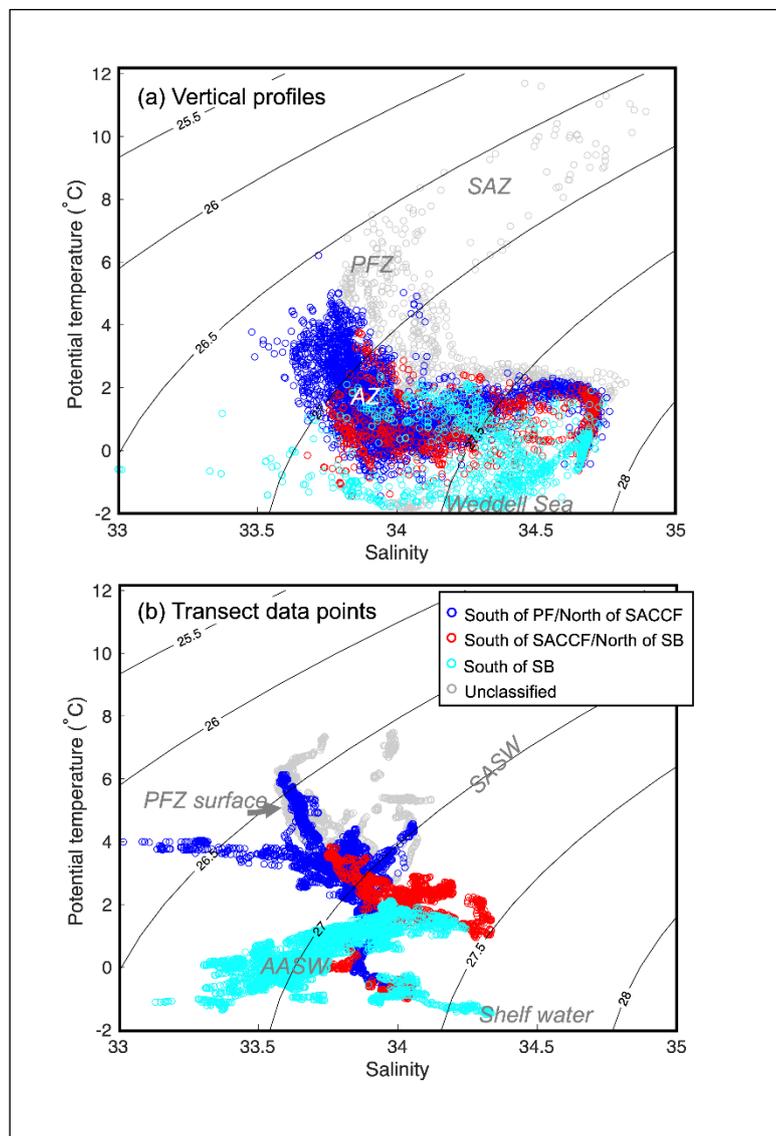
Oceanographically, the profile data spanned the SB, SACCF, PF and SAF (Fig. 6a). Antarctic Surface Water, Polar Frontal Zone surface water, and shelf waters were evident in the underway data (Fig. 6b).

265

Figure 6. Potential temperature-salinity plots for (a) CTD vertical profiles and (b) transect data points. Data have been colour coded according to their location relative to the long-term mean positions of the PF, SACCF and SB (see Fig. 1). SAZ – Subantarctic Zone, PFZ – Polar Frontal Zone, SASW – Subantarctic Surface Water, AASW – Antarctic Surface Water.

270 On repeated transects to the north of South Georgia (cruises JR17, JR28 and JR38) and across the Scotia Sea (JR161, JR177 and JR200), near-surface nutrient values (0 – 7 m) were compared with a mean value derived from CTD water bottle data (0 – 50 m) to assess whether surface values were representative of deeper parts of the water column (Table 3).

Table 3. Relationship between mean surface (0 to 7 m) nutrient data with those averaged over 0 to 50 m using linear regressions. All
275 **available data from 6 cruises were examined during 2 studies: (a) to the north of South Georgia with 50% of stations on-shelf (Whitehouse et al., 2009); (b) repeated transects across the Scotia Sea sampling deep oceanic waters (Whitehouse et al., 2012).**

Parameter	(a) Cruises JR17, JR28, JR38			(b) Cruises JR161, JR177, JR200		
	n	R^2	p	n	R^2	p
$SiOH_4$-Si	29	98%	<0.001	31	100%	<0.001
PO_4-P	31	94%	<0.001	29	93%	<0.001
NO_3-N	31	96%	<0.001	31	98%	<0.001
NH_4-N	31	87%	<0.001	29	69%	<0.001

280 Linear regressions for all comparisons were highly significant ($p < 0.001$). For $Si(OH)_4$-Si, PO_4-P, and NO_3-N, R^2 values were ≥93%. For NH_4-N, R^2 values were lower and a difference was observed between the South Georgia cruises (87%) and those in the Scotia Sea (69%). This was doubtless due to the different water column characteristics sampled during the two studies. The South Georgia cruises include many on-shelf stations to the north of the island where NH_4-N is biologically generated and constrained bathymetrically to the surface waters. Whereas for the offshore Scotia Sea stations, NH_4-N concentrations were

285 relatively low, pycnoclines were deeper and the upper mixed-layer frequently extended below 50 m (Korb and Whitehouse, 2004; Korb et al., 2012).

4. Data availability

The profile and underway sample data have been deposited at the UK Polar Data Centre and are publicly available in the NetCDF and CSV formats as of the date of publication, https://doi.org/10.5285/4014370F-8EB2-492B-A5F3-

290 6DC68BF12C1E (Whitehouse et al., 2022).

5. Code availability

This paper does not report original code.

6. Conclusions and potential use of the dataset

We have presented here a new macronutrient database, including depth profiles and continuous underway surface

295 measurements of silicic acid, phosphate, nitrate, ammonium, and nitrite, along with co-located temperature and salinity. Data were collected throughout the year from a variety of biological "hotspots" within the Southern Ocean, including South Georgia and the wider Scotia Sea, the Western Antarctic Peninsula, and the Bellingshausen Sea. One of the key challenges in understanding carbon cycling in the Southern Ocean is disentangling long-term responses from significant spatial and temporal variability in physical and biogeochemical parameters. As such, there is a critical need for regional long-term observational

300 datasets that are openly accessible to generate a better mechanistic understanding of the drivers of primary production. The

new data product described here provides an unprecedented view of biogeochemical cycling in biologically productive regions of the Southern Ocean across a critical period in recent climate history, and illustrates the importance of FAIR (Findable, Accessible, Interoperable, and Reusable) sharing of scientifically valuable observational datasets.

7. Appendix 1

305 Further information is available for most of the cruises during which data for the current database were collected. This includes the specific aim of each cruise, methodology and preliminary results.

Cruise reports are listed in chronological order:

310 Heywood, R. B.: RRS John Biscoe Cruise JB04: Offshore Biological Programme, BODC Cruise Inventory, 32 pp., https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/john_biscoe4_83.pdf, 1983.

Priddle, J.: RRS John Biscoe Cruise JB08: South Georgia and Bransfield Strait Marine Biology, BODC Cruise Inventory, 52 pp., https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/john_biscoe08.pdf,
315 1988.

Watkins, J. L. and Priddle, J.: RRS John Biscoe Cruise JB10: South Georgia Marine Biology, BODC Cruise Inventory, 12 pp, https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/john_biscoe10_90leg1_2.pdf, 1990.

320 Owens, N. J. P.: RRS James Clark Ross Cruise JR02: Biogeochemical Ocean Flux Study, BODC Cruise Inventory, 245 pp, https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/jr02_92.pdf, 1992.

White, M.: RRS James Clark Ross Cruise JR06: South Georgia and South Orkneys Marine Biology (Predator/Prey cruise), BODC Cruise Inventory, 218 pp, https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/jr06.pdf, 1994.
325
Priddle, J. and Swanson, C.: RRS James Clark Ross Cruise JR11: Marine Life Sciences Pelagic Ecosystem Studies, BAS Cruise Archive, 46 pp, 1996.

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Cruise reports are not available for JB03, JB05 or JB06.

8. Author contributions

MJW, KRH, GAT, SET and PTH conceived the data paper and wrote the manuscript. All authors commented on the paper and contributed to the quality check.

370 ## 9. Competing interests

The authors declare that they have no conflict of interest.

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