Supplement of Biogeosciences, 17, 3815–3835, 2020
https://doi.org/10.5194/bg-17-3815-2020-supplement

Biogeosciences Open Access EGU

Supplement of

The Southern Annular Mode (SAM) influences phytoplankton communities in the seasonal ice zone of the Southern Ocean

Bruce L. Greaves et al.

Correspondence to: Bruce L. Greaves (bruce.on.aria@gmail.com)

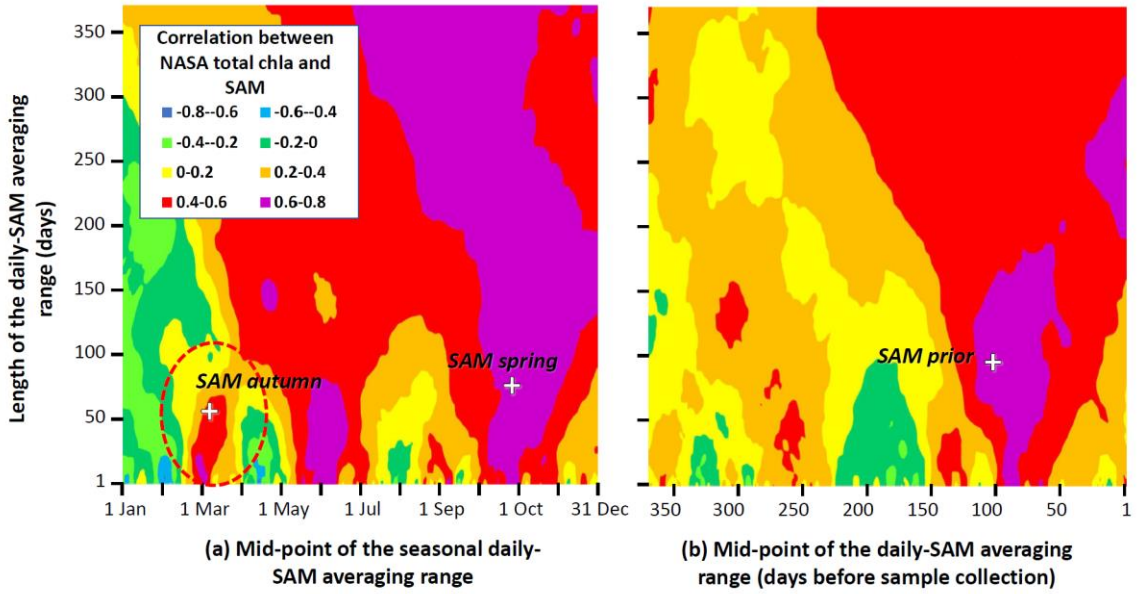

Figure S1. Response surfaces of the correlation between NASA satellite total chlorophyll and the averaged SAM, versus timing and length of the SAM period averaged. The SAM period is the number of days of daily-SAM averaged (vertical axis) and the timing of the range of averaged daily-SAM (horizontal axis). The SAM maxima identified in Figure 3 are shown (***SAM autumn***, ***SAM spring*** and ***SAM prior***). Evident maxima in autumn are indicated with red broken-line loops. The x-axis is expressed as: (a) the time through the calendar year of the middle of the averaged daily-SAM range; and (b) the number of days before a sample was collected, to the middle of the daily-SAM range.

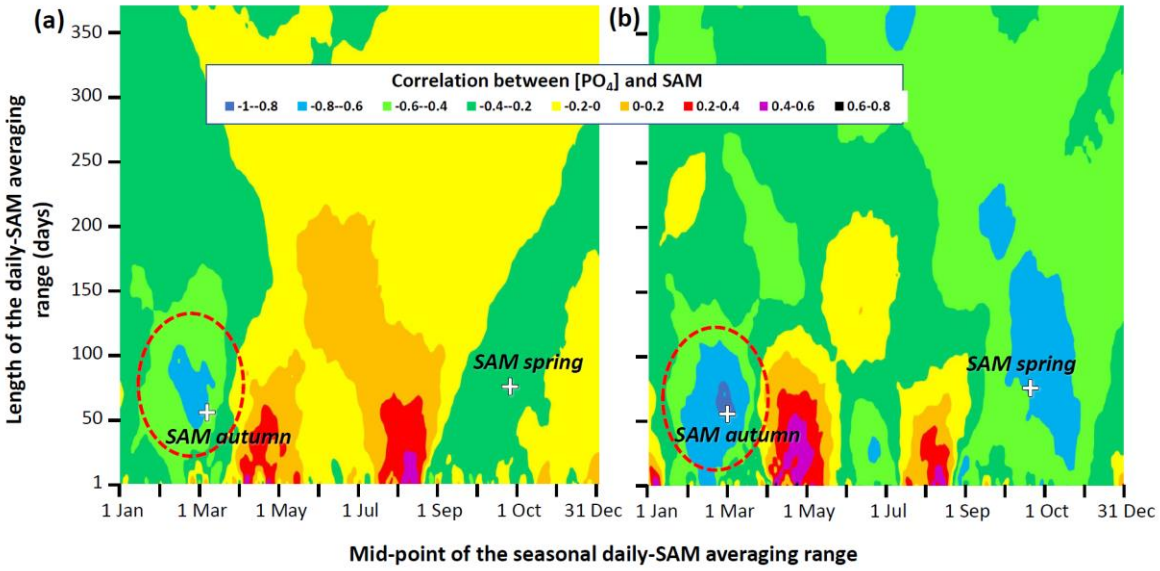

Figure S2. Response surfaces of the correlation between [PO_4] and the averaged SAM, versus timing and length of the daily-SAM averaging range, i.e. the calendar date of the mid-point of the date range (horizontal axis), and the number of days over which those indices were averaged (vertical axis), respectively. The SAM maxima identified in Figure 3 are shown (SAM autumn, SAM spring). Evident maxima in autumn are indicated with red broken line loops. (a) Analysis includes all available data (n=51), (b) analysis includes only half of the samples, being those collected later in the spring-summer productive season (n=26).

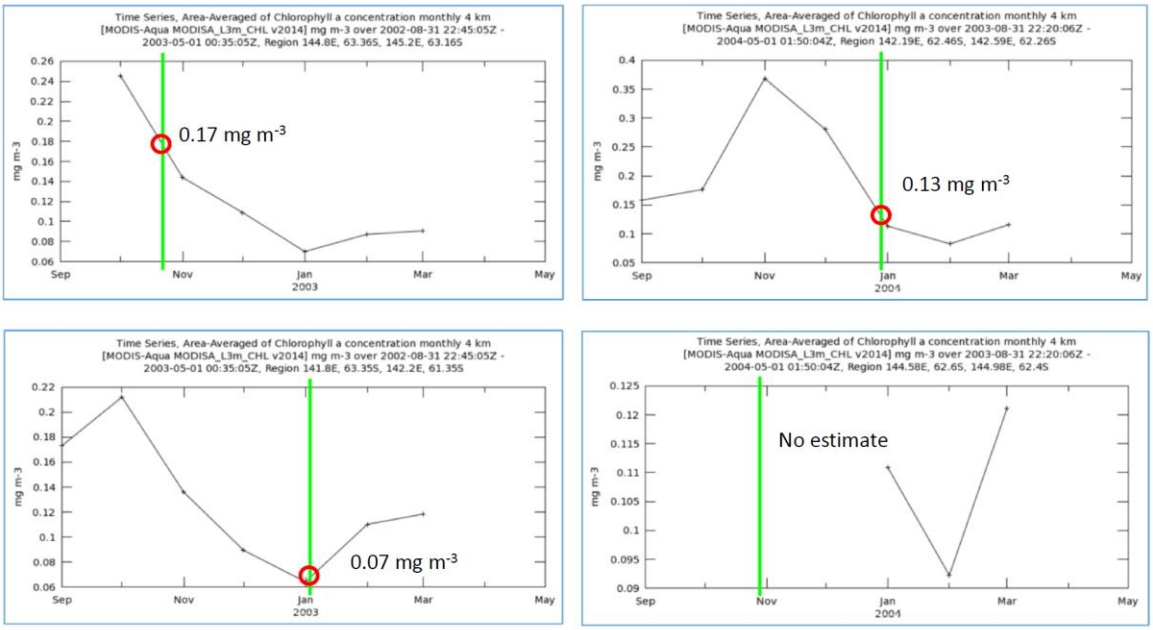

Figure S3. Examples of estimates of satellite total chlorophyll. Charts are temporal estimates of month average total chlorophyll (Acker and Leptoukh 2007, GMAO 2017), across the spring summer of the sample collection, averaged over a region 0.4 degrees of longitude by 0.2 degrees of latitude around the sample collection location (total area about 20 x 20 km). The total chlorophyll at the time of sampling (time of sampling indicated with a green line placed over the temporal chart), was interpolated from the available points (red circle) from and is the number depicted on the chart. The bottom-right chart depicts a sample for which total chlorophyll could not be estimated.

Supplemental Material, Table S1. Pairwise correlations between the relative abundances of 22 phytoplankton taxa. Significant correlations at p<0.05 are in bold/italics, those significant at Bonferroni-adjusted p<0.05/21 are also underlined.

r	ca	cca	cc	cd	cn	cyc	da	dt	ds	dcx	fcx	fk	fps	fr	fri	guc	ehu	nix	parm	pet	psl
cca	0.11																				
cc	***0.40***	-0.12																			
cd	0.25	-0.05	***0.47***																		
cn	***0.36***	0.16	***-0.28***	-0.26																	
cyc	-0.03	-0.07	-0.07	0.01	-0.02																
da	***0.43***	0.07	0.26	***0.40***	-0.02	0.14															
dt	-0.26	0.12	***-0.38***	***-0.42***	0.14	-0.17	-0.20														
ds	0.22	***0.59***	-0.27	***-0.32***	***0.58***	-0.11	-0.03	***0.29***													
dcx	***0.31***	0.26	0.02	0.02	***0.36***	-0.15	0.07	-0.09	***0.47***												
fcx	-0.27	-0.22	-0.07	-0.27	-0.26	-0.08	-0.23	-0.12	***-0.36***	***-0.61***											
fk	0.26	-0.07	***0.39***	0.27	-0.20	0.04	***0.29***	***-0.42***	-0.15	0.14	-0.26										
fps	0.15	-0.09	-0.10	-0.10	-0.02	-0.12	-0.04	-0.10	0.02	0.20	-0.01	0.08									
fr	***-0.52***	-0.21	***-0.28***	***-0.44***	-0.26	0.15	***-0.34***	0.14	-0.22	-0.20	0.03	-0.18	-0.15								
fri	-0.02	-0.05	***0.33***	-0.03	-0.12	-0.25	-0.02	0.04	-0.17	-0.20	0.19	-0.02	0.15	-0.08							
guc	0.03	-0.14	0.23	-0.12	0.00	***0.28***	0.26	***-0.30***	-0.08	0.03	-0.01	0.08	-0.18	0.26	-0.10						
ehu	-0.25	0.06	-0.13	-0.25	-0.06	0.04	-0.21	0.24	0.20	0.25	***-0.34***	-0.08	0.13	0.17	-0.02	-0.01					
nix	-0.20	***0.31***	***-0.41***	***-0.50***	0.16	0.08	-0.15	***0.45***	***0.41***	0.02	-0.10	***-0.42***	-0.09	0.09	0.02	-0.13	***0.41***				
parm	-0.08	***0.36***	-0.23	-0.25	***0.52***	-0.03	-0.08	0.11	***0.49***	0.27	-0.17	-0.23	-0.19	-0.13	-0.05	-0.02	0.01	0.25			
pet	-0.14	0.10	-0.08	-0.16	-0.12	-0.10	-0.22	0.20	0.19	0.23	-0.20	-0.08	***0.39***	-0.14	-0.09	-0.11	***0.66***	***0.40***	-0.04		
psl	***0.48***	0.08	0.08	0.05	***0.29***	0.02	0.06	-0.22	***0.31***	***0.52***	***-0.39***	***0.31***	***0.51***	***-0.49***	-0.08	0.00	0.17	-0.06	0.01	***0.38***	
ta	***0.32***	0.02	0.18	-0.13	0.12	0.00	0.09	-0.19	0.14	0.23	-0.18	***0.65***	0.06	-0.22	-0.08	0.11	0.03	-0.20	-0.01	-0.01	***0.56***

Supplemental Material, Table S2. Environmental variables showing summary statistics for each environmental variable and pairwise correlations among variables, and between environmental variable and taxa abundances. Correlations associated with p<0.05 are shown underlined, and correlations associated with Bonferonni-adjusted p<0.0028 and p<0.0026 for correlations among environmental variables and correlations between environmental variables and taxa abundances respectively, are in bold. Note, some covariates (year, SAM, min.lat.ice) are annual estimates (only 11 annual values from 2002 to 2012.

	D	***SAM_autumn***	***SAM_prior***	***SAM_spring***	***LAT.S***	***LONG.E***	***DSSI***	***TimeUTC***	***min.lat.ice***	***SST***	***S***	***Y***	***NO_x***	***PO_4***	***SiO_4***
unit	days	index	index	index	˚S	˚E	days	fraction	˚S	˚C	PSS	year	μM	μM	μM
average	95.83	0.00	0.065	-0.21	63.26	142	65.12	0.504	-61.7	0.635	33.75	2007	27.13	1.677	26.13
min	19.96	-0.66	-1.35	-1.49	62.13	135.8	-26	0	-62.8	-1.8	33.2	2002	23.49	1.21	8.93
max	150.9	0.62	1.957	1.14	64.32	147.9	366	0.984	-60.5	2.977	34.14	2012	31.08	2.08	55.64
n	52	11	52	11	52	52	52	52	11	52	52	11	51	51	51
SAM_autumn	***0.32***														
SAM_prior	-0.06	***0.51***													
SAM_spring	0.04	0.56	***0.83***												
LAT.S	0.25	0.16	-0.03	-0.01											
LONG.E	***-0.63***	-0.17	0.10	0.05	***-0.31***										
DSSI	***0.56***	0.18	-0.03	0.07	***-0.27***	-0.27									
TimeUTC	0.09	***0.29***	***0.30***	***0.31***	-0.18	0.20	0.09								
min.lat.ice	0.20	0.13	-0.18	0.00	-0.13	0.00	-0.13	-0.03							
SST	***0.92***	0.27	-0.14	-0.03	0.10	***-0.68***	***0.60***	0.04	0.19						
S	***-0.43***	-0.14	***0.31***	0.21	-0.14	0.23	-0.13	0.24	***-0.61***	***-0.41***					
Y	0.18	0.27	***0.35***	0.32	0.01	-0.24	0.02	0.23	0.32	0.27	-0.06				
NO_x	***-0.77***	***-0.39***	0.23	0.04	-0.09	***0.53***	***-0.43***	-0.03	***-0.30***	***-0.72***	***0.54***	-0.14			
PO_4	***-0.73***	***-0.56***	-0.07	-0.26	-0.22	***0.62***	***-0.52***	-0.04	0.03	***-0.70***	***0.39***	-0.13	***0.73***		
SiO_4	***-0.56***	***-0.42***	0.26	-0.05	0.09	***0.40***	***-0.49***	-0.07	-0.01	***-0.63***	***0.39***	0.09	***0.72***	***0.75***	
ca	-0.15	***0.55***	***0.57***	***0.63***	-0.08	0.20	-0.01	0.24	-0.25	-0.20	0.22	0.13	0.14	-0.10	-0.05
cc	***0.37***	***0.36***	0.27	***0.35***	0.01	-0.07	0.27	0.08	-0.05	0.25	-0.14	0.11	***-0.42***	***-0.48***	***-0.29***
cca	***-0.36***	-0.02	0.26	0.20	-0.22	***0.41***	-0.12	0.01	0.11	***-0.36***	-0.07	-0.07	***0.36***	***0.35***	***0.29***
cd	***0.48***	***0.38***	***0.31***	***0.29***	0.12	-0.13	***0.37***	0.16	-0.01	***0.35***	-0.17	0.20	***-0.32***	***-0.38***	-0.23
cn	***-0.70***	-0.06	***0.42***	0.24	-0.08	***0.48***	***-0.40***	0.05	***-0.33***	***-0.69***	***0.56***	-0.04	***0.71***	***0.52***	***0.60***
ehu	***-0.28***	***-0.38***	***-0.42***	***-0.38***	-0.16	0.21	0.12	-0.16	-0.13	-0.25	-0.01	***-0.37***	0.22	0.25	0.02
cyc	0.13	0.09	-0.10	-0.03	0.01	0.02	***0.32***	0.24	-0.19	0.12	0.02	-0.11	-0.14	-0.23	-0.24
da	0.18	***0.37***	***0.34***	***0.27***	-0.10	-0.06	0.18	0.14	-0.05	0.13	-0.08	0.06	-0.11	***-0.34***	-0.22
dcx	***-0.57***	0.15	0.06	0.24	-0.18	***0.52***	-0.11	0.01	-0.20	***-0.57***	0.21	-0.15	***0.38***	***0.32***	0.13
ds	***-0.78***	-0.17	***0.30***	0.14	***-0.28***	***0.68***	***-0.41***	0.18	-0.18	***-0.75***	***0.36***	-0.14	***0.69***	***0.68***	***0.50***
dt	-0.18	***-0.44***	-0.08	-0.16	-0.18	0.16	-0.19	0.06	0.09	-0.17	0.23	-0.02	***0.39***	***0.44***	***0.33***
fcx	0.26	-0.06	-0.08	-0.09	0.27	***-0.58***	-0.08	-0.13	0.10	***0.35***	-0.12	0.24	-0.20	***-0.29***	-0.08
fk	0.23	***0.52***	0.16	0.25	-0.07	-0.07	0.19	-0.06	0.18	0.22	***-0.46***	-0.05	***-0.38***	***-0.43***	***-0.41***
fps	-0.13	0.22	-0.02	0.22	0.08	-0.10	-0.05	-0.09	-0.09	-0.03	0.12	0.22	0.07	0.02	-0.06
fr	0.16	***-0.39***	***-0.58***	***-0.57***	-0.09	-0.13	0.13	-0.06	0.10	0.22	-0.12	-0.24	***-0.30***	-0.01	-0.21
fri	0.11	-0.10	0.00	-0.03	0.02	-0.02	0.02	-0.17	-0.02	0.10	-0.03	0.03	-0.06	-0.07	0.00
guc	0.09	0.12	-0.06	-0.06	-0.10	0.05	0.17	0.12	0.07	0.10	-0.03	-0.02	***-0.29***	***-0.28***	-0.24
nix	***-0.47***	***-0.45***	***-0.29***	***-0.31***	-0.12	***0.42***	***-0.32***	-0.11	0.02	***-0.46***	0.09	-0.22	***0.38***	***0.50***	***0.28***
parm	***-0.60***	***-0.29***	0.15	-0.09	0.08	***0.42***	***-0.42***	-0.19	-0.18	***-0.65***	***0.36***	***-0.28***	***0.60***	***0.53***	***0.70***
pet	-0.25	-0.13	***-0.27***	-0.08	-0.02	0.15	-0.17	-0.12	0.11	-0.25	0.02	-0.02	0.13	0.26	0.08
psl	***-0.35***	***0.39***	0.19	***0.37***	-0.11	***0.36***	-0.09	0.12	-0.10	***-0.35***	0.18	0.01	0.20	0.22	0.03
ta	-0.16	***0.32***	0.12	0.16	-0.18	0.15	-0.11	-0.07	0.14	-0.11	-0.19	-0.15	0.00	-0.01	-0.14

Table S3: Analysis of absolute abundance. Variance in the community composition of 22 phytoplankton taxa-groups attributable to constraining environmental covariables in the CAP analysis.

CAP analysis	variance category		variance	fraction of total variance	p
(a) Variables fit individually as the only constraining covariate		***D***	0.63	**13.9%**	<0.001
		SST	0.58	**12.8%**	<0.001
		SAM_autumn	0.49	**10.9%**	<0.001
		LONG.E	0.45	**9.9%**	<0.001
		SAM_spring	0.41	**9.1%**	<0.001
		SAM_prior	0.42	**9.2%**	<0.001
		DSSI	0.27	**6.1%**	0.003
		S	0.24	**5.3%**	0.004
		Y	0.17	**3.8%**	0.041
		LAT.S	0.11	**2.5%**	0.223
		Minimum latitude of sea-ice the previous winter	0.08	**1.8%**	0.467
(b) Optimum multi-parameter model	variance explained by all constraining covariables		1.60	**35.6%**	<0.001
	individual constraining covariables	***D***	0.63	**13.9%**	<0.001
		SAM_autumn	0.48	**10.7%**	<0.001
		SAM_prior	0.19	**4.1%**	0.007
		Y	0.17	**3.7%**	0.007
		DSSI	0.14	**3.1%**	0.018
	Unexplained residual		2.90	64.4%	
	Total variance in taxa-composition between samples		4.50	100%	

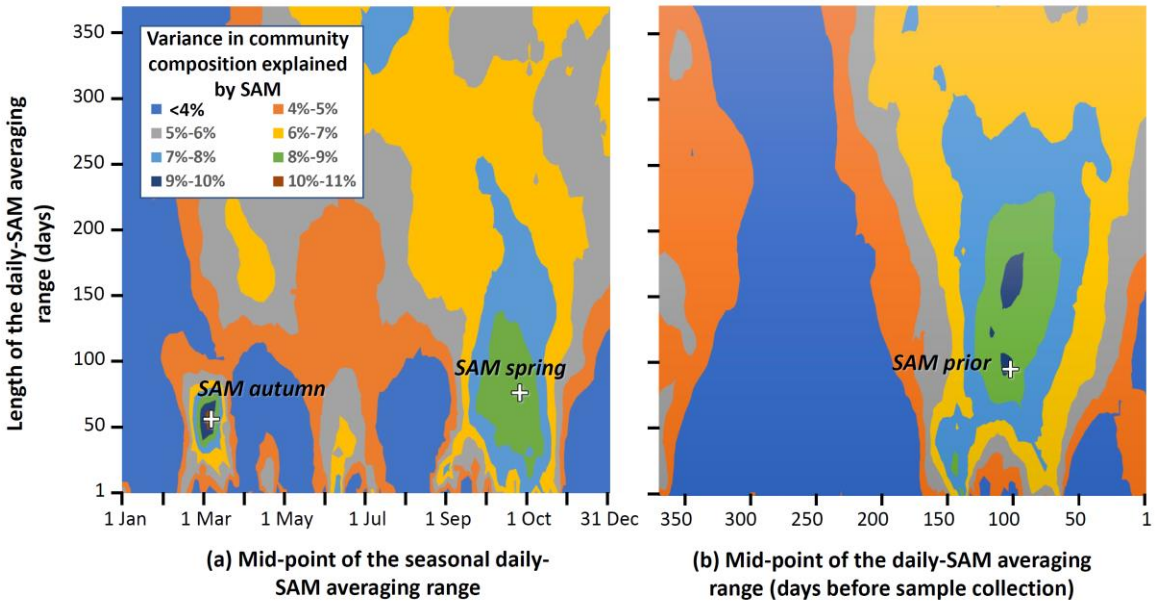

Figure S4: Analysis of absolute abundance. Variance in phytoplankton community composition explained by the SAM, versus timing and length of the averaged range of daily-SAM values. Response surfaces relate the fraction of total variance in phytoplankton community composition attributable to the SAM, versus the number of days in the range of averaged daily-SAM (vertical axis) and the timing of the centre of the range of averaged daily-SAM (horizontal axis). The horizontal axis is expressed as: (a) the time through the calendar year of the middle of the range; and (b) the number of days before a sample was collected, to the middle of the range. Three obvious maxima are identified with crosses (SAM autumn, SAM spring and SAM prior).

Table S4: Analysis of absolute abundance. Correlations between taxa-group relative abundances and environmental variables. Correlations significant at p<0.05 are in bold italics, correlations significant after Bonferroni adjustment are also underlined (p<0.05/19 for correlations among environmental variables, p<0.05/20 for correlations with taxa-group relative abundance).

taxa-code	taxa group	*D*	*SAM_autumn*	*SAM_prior*	*SAM_spring*	*LONG.E*	*DSSI*	*SST*	*S*	*Y*
ca	*Chaetoceros atlanticus*	0.18	***0.51***	***0.44***	***0.48***	-0.08	0.07	0.06	-0.02	0.18
cc	*Chaetoceros concavicornis/curvatus*	***0.39***	***0.33***	0.24	***0.31***	-0.10	0.21	***0.27***	-0.19	0.21
cca	*Chaetoceros castracanei*	-0.08	0.07	0.12	0.16	0.05	-0.02	-0.11	-0.26	-0.02
cd	*Chaetoceros dichaeta*	***0.49***	0.24	0.21	0.15	-0.20	***0.28***	***0.34***	***-0.31***	0.22
cn	*Chaetoceros neglectus*	***-0.51***	***-0.30***	-0.01	-0.24	0.21	***-0.39***	***-0.53***	***0.31***	-0.23
cyc	*Cylindrotheca closterium*	0.13	-0.04	-0.19	-0.19	-0.02	0.15	0.11	-0.10	-0.04
da	*Dactyliosolen antarcticus*	***0.31***	0.27	0.17	0.12	-0.23	0.10	0.22	-0.24	0.18
dcx	discoid centric	-0.26	-0.04	-0.25	-0.10	0.19	-0.17	***-0.30***	-0.06	-0.12
ds	*Dictyocha speculum*	***-0.67***	***-0.40***	-0.09	***-0.29***	***0.48***	***-0.42***	***-0.69***	0.23	***-0.34***
dt	*Dactyliosolen tenuijunctus*	0.01	***-0.48***	***-0.37***	***-0.40***	-0.07	-0.13	0.02	0.05	-0.05
ehu	*Emiliania huxleyi*	***-0.29***	***-0.43***	***-0.40***	***-0.46***	0.18	-0.13	***-0.29***	0.02	***-0.37***
fcx	*Fragilariopsis cylindrus/curta*	0.17	0.12	0.06	0.08	***-0.51***	-0.07	0.24	-0.04	0.21
fk	*Fragilariopsis kerguelensis*	***0.31***	***0.40***	0.06	0.15	-0.13	0.14	0.27	***-0.54***	0.06
fps	*Fragilariopsis pseudonana*	0.06	0.07	-0.06	0.08	***-0.34***	-0.02	0.18	0.00	***0.33***
fr	*Fragilariopsis rhombica*	0.09	***-0.44***	***-0.55***	***-0.58***	-0.21	-0.09	0.17	-0.12	-0.03
fri	*Fragilariopsis ritscheri*	0.17	-0.11	-0.03	-0.06	-0.06	0.01	0.17	-0.04	0.09
guc	*Guinardia cylindrus*	0.10	0.07	-0.13	-0.13	0.03	0.01	0.13	-0.13	0.12
nix	*Nitzschia acicularis/decipiens*	-0.26	***-0.41***	***-0.40***	***-0.42***	0.14	***-0.28***	-0.26	0.02	-0.13
parm	*Parmales spp.*	***-0.50***	***-0.36***	-0.10	***-0.30***	***0.28***	***-0.36***	***-0.54***	***0.36***	***-0.36***
pet	*Petasaria heterolepis*	***-0.27***	-0.16	***-0.30***	-0.11	0.15	-0.19	***-0.29***	0.01	-0.04
psl	*Pseudo-nitzschia lineola*	-0.05	***0.33***	0.04	0.19	0.11	-0.03	-0.12	-0.20	0.06
ta	*Thalassiothrix antarctica*	0.03	***0.29***	0.03	0.08	0.00	-0.06	0.06	***-0.39***	-0.13