Answers to reviewer 1

In this paper, the authors aim to examine the variations in and environmental controls of primary productivity in the Amundsen Sea based on a bioregion approach. They divided the study area into nine bioregions based on cluster analysis, and examine the environmental controls for NPP in different regions. This paper has the potential to offer new insights into how and why environmental factors affect NPP differently in different regions. However, if any, such insights are largely lost in the fragmented and disorganized presentation of results and discussions and inconsistent application of analysis methods. The authors presented their results as if certain environmental factors only affect NPP in certain bioregions, for example NPP is affected by Fe and dissolved ions in bioregion 3 and 5, but is largely controlled by SST and sea ice thickness in bioregion 8 and 9. However, the impacts of SST, sea ice, Fe and other factors on NPP should exist for all bioregions, but at different relative importance. When analyzing these factors, the authors used correlation analysis and presented correlation coefficients only for some environmental factors in some bioregions. It should be applied to all environmental factors for all bioregions, and all results should be reported regardless their statistical significance. Only in this way, one can make meaningful comparison on how environmental controls differ in different bioregions. In addition, this study is largely descriptive on the variations of NPP and environmental controls without any meaningful discussion and exploration of why such differences exist. Based on these concerns, I would not recommend its publication without major revisions in the ways I outlined above.

Answer: We greatly appreciate the referee for spending time on reviewing our manuscript and for the constructive comments. We have made careful considerations on the referee's comments, and have implemented most of the referee's suggestions. We hope to fulfill the requirements given by your review. Please see our responses in detail below.

We have added the correlation between and environmental factors in Table 3. The environmental controls of primary productivity of 6 and 7 (3 and 5 in the primary manuscript) showed some differences with that of bioregions 8 and 9. These differences may be caused by the differences of the dissolved iron concentrations. The dissolved iron concentrations in bioregions 8 and 9 were the highest in the Amundsen Sea area (Figure 5), so dissolved iron was not the limiting factor for primary productivity in these two bioregions. So in bioregion 8 and 9 the decadal

and long-term changes of primary productivity were more correlated with the SST and sea ice. In bioregion 6 and 7, the dissolved iron concentrations were much smaller than that of bioregion 8 and 9. The primary productions were also positive correlated with SSTs and negative correlated with sea ice thickness, but the effects of changes of SSTs and sea ice thickness were relative smaller than that of dissolved iron. So the primary production were mainly controlled by dissolved iron concentrations in bioregions 6 and 7. The spatial differences in the limitation of dissolved iron on the primary productivity of the Amundsen Sea were consistent with previous results (Gerringa et al., 2012; Yager et al., 2012; Alderkamp et al., 2015). We have added these discussions in the manuscript this time.

We have added some discussions to explain the processes behind the variation of parameters leading to changes in phytoplankton primary production in the manuscript this time. Including how environmental controls differ in different bioregions and what caused the variation of nutrients and how it could have affected the PP.

Table 3. Correlation between primary production and environmental factors of bioregion 6, 7, 8 and 9.

	SST (Nov-Mar)	Hice	Fe	nitrate	phosphate	silicate	mlp
Bioregion 6	0.12	-0.10	0.96	0.86	0.87	0.94	-0.18
Bioregion 7	0.07	-0.18	0.59	0.78	0.81	0.61	0.11
Bioregion 8	0.45	-0.54	0.11	0.08	0.13	0.07	-0.02
Bioregion 9	0.46	-0.24	-0.25	-0.15	0.20	-0.05	-0.15

Trends with significant at the 95% confidence level are underlined

In section 3.3

"The variation of these nutrients was caused by changes of the seasonal cycle of the sea ice in the offshore area in the Amundsen Sea. Stammerjohn et al. (2015) found that the winter ice season duration showed a rapid decrease since 2000 and the summer open duration showed a rapid increase since 2000 in the offshore area in the Amundsen Sea. Previous studies have shown that sea ice coverage in west Antarctica water and in the Amundsen Sea has decreased drastically over the last few decades (Stammerjohn et al., 2015; Randall-Goodwin et al., 2015). On the one hand, the melting sea ice is a potentially important source of dissolved iron, nitrate, phosphate, and silicate (Lannuzel et al., 2010). On the other hand, the melting sea ice can lead to salinity-driven vertical stratification (the "meltwater pump"), it can transport sediment-derived nutrients to the upper water column (St-Laurent et al., 2017; Twelves et al., 2021). Throughout much of the Southern Ocean, macronutrients are abundant and low Fe concentrations limit productivity (Tagliabue et al., 2014). Also, Alderkamp et al. (2015) showed that the primary production is stressed by limited iron availability while macronutrients are generally abundant in the Amundsen Sea. Alderkamp et al. (2015) indicated that primary productivity would be stressed by low iron concentrations during December and January in the Amundsen Sea. So the changes in dissolved iron resulted in increased primary production in November and December after 2000. Kwon et al. (2021) also found that the increase in iron can lead to a shift in the bloom peak timing to earlier than January in the Amundsen Sea continental shelf water (mostly in bioregion 5) using a 1-D pelagic ecosystem model."

Specific comments:

1. The numbering of the bioregions seems rather random to me, which makes it difficult to follow the results. It would be better if they are numbered in some logical way, for example along the latitudinal gradient.

Answer: We have modified the numbering of the bioregions along the latitudinal gradient.

2. Figure 5: I don't think this is an effective visualization. Please present these data either in a table format, or as a map matrix.

Answer: We have added these results in a table this time in the supplementary as Table S1.

Table S1. Values of the key properties of bioregions, including the including the annual maximum mean (A), annual minimum mean (B), and long-term change rate (C) (dep-A: latitudinal gradient, dep-B: longitudinal gradient)

		Bio 1	Bio 2	Bio 3	Bio 4	Bio 5	Bio 6	Bio 7	Bio 8	Bio 9
tem	K	278.75	277.07	276.03	274.23	272.46	271.59	271.45	271.53	271.57
tem-A		280.20	278.67	277.78	275.95	274.22	272.49	272.02	272.46	272.58
tem-B		277.65	275.8	274.51	272.78	271.41	271.27	271.27	271.27	271.25
tem-C		-0.0086	-0.0085	-0.0166	-0.0136	-0.0089	0.0040	0.0007	-0.0014	-0.0001
mlp	m	134.9	112.4	67.2	65.2	41.1	38.9	38.6	43.5	43.1
mlp-A		338.5	257.3	124.4	118.9	67.1	69.6	78.5	101.9	104.1
mlp-B		35.2	32.1	29.3	25.1	16.3	12.0	11.3	11.2	11.0
mlp-C		2.39	0.11	0.05	-0.02	0.06	0.26	0.36	0.42	0.42
ssh	m	-0.39	-0.77	-1.08	-1.26	-1.46	-1.62	-1.61	-1.59	-1.60
ssh-A		-0.29	-0.65	-0.95	-1.18	-1.41	-1.59	-1.58	-1.56	-1.55
ssh-b		-0.50	-0.89	-1.21	-1.35	-1.51	-1.65	-1.64	-1.63	-1.64
ssh-c		0.002	>-0.001	-0.002	>-0.001	0.001	0.001	<0.001	0.001	<0.001
bot	K	273.41	273.32	273.63	273.12	273.14	273.17	274.32	274.06	272.97
bot-A		273.45	273.36	273.73	273.14	273.15	273.18	274.38	274.21	273.24
bot-B		273.37	273.27	273.54	273.09	273.13	273.16	274.25	273.89	272.72
bot-C		0.001	0.001	-0.002	0.001	0.002	0.001	-0.001	0.003	-0.011
ice		0.99	0.94	0.79	0.57	0.26	0.067	0.023	0.033	0.040
ice-C		<0.001	-0.001	-0.002	-0.005	-0.001	0.002	0.001	>-0.001	0.001
sal		34.12	33.99	33.86	33.72	33.51	33.58	33.50	33.31	33.19
sal-A		34.19	34.08	34.01	33.87	33.77	33.98	34.01	34.00	34.06
sal-B		34.05	33.89	33.71	33.50	33.10	32.85	32.64	32.10	31.54

sal-C		-0.003	-0.002	-0.002	0.001	0.001	0.004	-0.001	-0.002	0.003
chl	Mg/m^3	0.34	0.32	0.36	0.33	0.31	0.30	0.29	0.57	0.756
chl-A		1.06	0.94	0.74	0.91	1.04	1.21	1.12	2.34	3.14
chl-B		0.06	0.08	0.18	0.09	0.05	0.03	0.04	0.03	0.04
chl-C		<0.001	<0.001	<0.001	<0.001	0.004	0.007	0.005	0.002	0.006
nppv	mg m-3 day-1	3.74	3.12	3.19	2.52	2.37	2.37	2.11	5.86	8.51
nppv-A		10.61	9.34	6.98	7.84	8.93	12.34	11.80	31.52	44.36
nppv-C		0.007	0.003	0.002	0.008	0.041	0.071	0.058	0.020	0.098
fe	mmol m-3	0.000173	0.000166	0.000124	0.000148	0.000158	0.000221	0.000353	0.000982	0.002536
fe-A		0.00031	0.00028	0.00021	0.00024	0.00026	0.00036	0.00062	0.00162	0.00397
fe-B		7.1E-05	7.3E-05	7.2E-05	7.2E-05	7.2E-05	8.4E-05	13.1E-05	46.9E-05	154E-05
fe-C		3.7E-06	4.6E-06	2.5E-06	5.2E-06	6.2E-06	7.7E-06	1.5E-06	-6.5E-06	-27.7E-06
dep	m	-4734	-4632	-3276	-4601	-4420	-3775	-918	-295	-87
dep-A		19.0	38.9	13.9	14.5	-36.7	-126.7	-270.3	-203.1	-151.4
dep-B		0.9	-4.3	-10.5	-5.7	-0.9	10.3	27.9	8.1	27.1

3. Lines 307-308: It is not clear to me why these four bioregions were selected. If it is based on long term NPP trend (those with NPP increase), as the paper seems to indicate, why did you exclude bioregion 1?

Answer: The bioregion 6 and 7 (3 and 5 in the primary manuscript) were selected for two reasons. First, the long-term change rate of bioregion 6 and 7 were larger than other bioregions (except bioregion 9). Second, the mean and annual maximum mean values of primary production of bioregions 6 and 7 were also the third and fourth largest after bioregion 8 and 9. We are sorry for not making it clear in the manuscript. We have modified the manuscript this time.

In section 3.3

“The results showed that the mean and annual maximum mean values of primary production in bioregions 8 and 9 were significantly larger than those in other bioregions. This is because the polynyas in the Amundsen Sea are located in bioregion 8 and 9. And the mean and annual maximum mean values of primary production of bioregions 6 and 7 were the third and fourth largest. The long-term change rate of bioregion 9 was the largest, followed by those of bioregions 6 and 7. Therefore, bioregions 6, 7, 8, and 9 were selected as typical bioregions with which to analyze variations in primary productivity in the Amundsen Sea.”

4. 7-10: The clustered bar charts are very difficult to read. Particularly for Fig. 9 and 10, they are impossible to read. Consider an alternative chart type, e.g. line charts.

Answer: We have modified the figure 9 and 10 according to your advice.

5. Lines 300-301: The seasonal cycle of Fe you described is only true for bioregion 9, and I do not see much seasonal variation of Fe in other bioregions. Could you please explain why Fe concentrations would show seasonal cycles?

Answer: There were also seasonal variation of Fe in the other 3 bioregions. We are sorry for not making it clear in the Figure 8. We modified this figure, the Fe anomaly of selected 4 bioregions were shown in Figure 8 this time.

The seasonal cycles of Fe are dominated by iron scavenging and by remineralization (St-Laurent et al., 2019). In December and January, the primary production increase rapidly and provided a large inventory of sinking biogenic particles, the scavenging increases rapidly during this period. Over the rest of the year, scavenging decreases gradually. From January to June the Fe gradual recovery through remineralization of organic particles or the dissolution/solubilization of surface bound labile particulate iron. We have added this in section 3.3.

6. For Fig. 11, how did you calculate the annual NPP? Did you use the usual calendar year? It is better to use July-June, rather than Jan-Dec, because July-June year could cover the whole growing season for each year. Otherwise, a shift of max NPP from Jan to Dec, as you mentioned before, could create an artificial jump in NPP observed in Fig. 11a (Bioregion 3).

Answer: Thanks for the advice. We calculated the annual NPP using July-June, and have modified the figure 11 according to your advice. However, the results changed little compared with the last version.