This file includes the responses to review1 and review 2.

Responses to review1:

Summary:

Xu and colleagues investigate the regional sea surface $p\mathrm{CO}_2$ and air-sea flux in the Prydz Bay Antarctica using observations from the CHINARE cruise in February 2015. The authors divide the study regions into 3 sub-regions, based on the physical and biogeochemical controls of these sub-regions. Using a self-organizing map approach, the authors extrapolate the cruise data to the entire study region in order to estimate the carbon exchange of the Prydz Bay.

The Southern Ocean is still among the least observed and certainly least well understood ocean basins, hence I found this process study – investigating carbon variability and air-sea exchange in the Prydz Bay – to be very interesting and certainly relevant for the GB readership. More details on the strengths and weaknesses are listed below.

Strengths:

I found the manuscript and particularly the discussion of the processes comprehensive and logically built-up. The authors further make use of an appropriate and previously applied method based on machine learning (i.e. the SOM method) to extrapolate the cruise information to the full region of interest. They use independent validation data to test how well their approach reproduces observations from the SOCAT dataset and use this information to estimate the uncertainty of their integrated air-sea flux.

Weaknesses:

Up-front, I would like to note that there are several language issues – too many to be all named here (just one example: line 232: "In Pacific Ocean" should be "In the Pacific Ocean") – hence I do recommend English language editing.

During my review, I have encountered a few things that need clarification or some more information from the authors. They are listed from the most to least concerning. Additional comments (not of major concern) with line-numbers can be found at the end of this document:

1. Method section: At the moment, it is impossible for a reader who has not worked with the SOM approach to understand the methods section. Sentences like: "The SOM is trained using unsupervised learning to project the input space of training samples to a feature space (Kohonen, 1984), which is usually represented by grid points in tow-dimension space." Imagine a BG reader who is interested in the carbon exchange of the Prydz Bay but has never worked with a SOM. How is that person supposed to understand wording like"unsupervised, feature space, weight vector, training data, labeling data, etc." without reading several other papers first? As a SOM user I had no issues to follow this section but in my view, it has to be simplified for the more general BG audience. Furthermore, the authors miss to mention what distance function the SOM uses to detect the "winner neuron" (Euclidean distance maybe?). Furthermore, I don't think the phrase "resolve nonlinear relationships" (see abstract) is appropriate, since a SOM is a clustering algorithm that clusters based on similarities, but does not explicitly "resolve" a relationship.

Response: We have revised the introduction part about the SOM method to make it easy to understand what is SOM. And in the 2.2 section we have revised the sentences and adjusted the structure to make it easy for the reader to know how SOM works. In our SOM analysis we used Euclidean distance (the shortest distance) to select winner neurons and we have added this to the manuscript. We agree with the reviewer's suggestion and have changed the phrase 'resolve nonlinear relationships' to be 'to overcome a complex relationship among the biogeochemical and physical conditions in the Prydz Bay region'.

2. Training data: This links a bit to my point above but goes a bit more in-depth: I am not sure how data have been handled. On line 177 the authors state that the data have been "the four proxy parameters were logarithmically normalized" but table 1 suggests otherwise. In table 1 all values are absolute values. Besides that, I am not convinced that it makes sense to logarithmically normalize all 4 proxies. It makes sense for the skewed MLD and CHL-a but not really for salinity and temperature. Besides, I wonder how the normalization effects the distance function (which is not mentioned). Euclidean distances depend on the data-value range of each proxy. Also, what I am missing is a discussion why exactly the 4 proxies have been chosen? Why not sea surface height, wind speed, sea level pressure? What makes the 4 proxies so unique? I know they have been used by other authors, but the reader of THIS study needs this information.

Response: In table 1 all values are absolute values of the four proxies to show the value range. For the skewness and the N coverage percentage, the normalized data are shown in parenthesis. According to the change of skewness and N coverage percentage we found out only MLD and Chla data needed to be normalized for both the training and labeling dataset. Since we used Euclidean distance function to select the winner neuron and it depends on the data-value range of each proxy. The normalization for MLD and Chla dataset is to avoid weighting issue raised from the different magnitude among the variables.

In section 2.1 we have discussed the four proxies which will affect the distribution of *p*CO_2 in the surface sea water. The dissolution of CO_2 into water is mainly affected by temperature and pressure of water. The variation of salinity has little effect on the dissolution of CO_2. However the sea ice changed quickly in the study region and we chose salinity to be a proxy to simulate *p*CO_2. Moreover, in the region where local biology activities are active, *p*CO_2 will be affect strongly by photosynthesis. The mixed layer depth will prevent the upward mixing of nutrients and limits the biological production therefore we chose MLD as another proxy to simulate *p*CO_2. Sea surface height and sea level pressure are not major factors to the distribution of oceanic *p*CO_2. Wind speed is vital for the sea-air gas exchange and it is included in the air-sea flux equation.

3. Uncertainty: line389 states: "increased from week-1 (2.13 TgC) to week-2 (2.24TgC) due to increased wind speed." I was a bit disappointed here. First there is the effort to calculate uncertainties, then it is neglected in the text. Given the final uncertainty estimate, it is very unlikely that this regional difference of 0.1 TgC is significant. In general I suggest to add uncertainties wherever possible to avoid such misinterpretations.

Response: We have added uncertainties to the carbon uptake in section 3.4 and we have changed 'increased' to be 'changed mildly'.

4. Validation, comparison: I appreciate that the authors do a comparison with SOCAT data and include this in the overall flux uncertainty. I think that there need to be a bit more info in the text what cruise from SOCAT you are comparing to (this information is available on socat.info), or what the average spatial and temporal distance (which should be possible

since a nearest grid method was used) between the cruises is. That certainly contributes to the mismatch as well. Otherwise, I was quite impressed by the relatively small (~22µatm) difference. It might not sound small at first but your are comparing small special scale and high frequency temporal scale data based on the extrapolation of a single cruise. Therefore, 22µatm is impressive in my view. Furthermore, the RMSE tells the reader about the spread, but it would be valuable to add the mean (or absolute mean) difference between the SOM derived CO_2 and the SOCAT cruise. This would give you an indication of the bias.

Response: We have added the information of the cruise we selected from SOCAT in section 2.3. We have calculated the absolute mean difference between the SOM derived CO_2 and the SOCAT cruise. According to the validation, the SOM derived pCO_2 is generally lower than the SOCAT. Since the dataset from SOCAT does not cover the low- pCO_2 area towards the south, the precision might be of great uncertainty.

Methods section: On many occasions the authors re-grid data to the desired 0.1*0.1 resolution, but a bit more information on all data that were regridded and the algorithm would be appreciated. Ideally in form of a table. Additionally, I am missing the motivation why 0.1*0.1 was chosen. Why not 0.5*0.5 or even 0.05*0.05. Just to be clear, I don't suggest changing the resolution, but the text needs some motivation/technical explanation on why the current resolution was chosen that justifies all the data handling (i.e. regridding of proxy data)

Response: The 0.1*0.1 resolution of our study was desired according to the study area. It is a small area from 63E to 83E and 64S to 70S and the 0.1 resolution is the optimal. In the paper of Telszewshi et al. (2009), it was a basin-wide area from 9.5E to 75.5E and 10.5N to 75.5N, so their resolution was a 1 latitude by 1 longitude resolution. For a global area, Takahashi et al.(2012) chose 4*5 resolution. For our study area, it would be too rough if the resolution of 0.5, and the matrices would be too big if the resolution of 0.05.

The other data including remote sensing data and modeled data of different resolution were regridded to be the same resolution of 0.1 * 0.1 by Kriging method. We have added some explanation in the text. We think it is clear in the text.

Recommendation:

I have found this study to be interesting and to be of value to the BG readership. While I have raised some (partly major) concerns above I think that they can be resolved by the authors. I therefore recommend major revisions of the manuscript.

Specific and minor comments to the text:

1. Abstract line 14: Please also add the temporal resolution to the spatial resolution

   Response: We have added 'weekly' to the spatial resolution in abstract.

2. Abstract lines 27-29: This last sentence is out of context and is not something you can conclude from this study, hence it needs to be removed.

   Response: We have removed the last sentence.

3. Lines 32-33 reads "The role of the ocean south of 60S in the transport of CO_2 to or from the atmosphere is still uncertain despite of its importance of reducing anthropogenic CO_2

in the atmosphere" – that is a conflicting statement as it currently reads. If we know the importance of reducing atmospheric CO_2 how can its role be uncertain?

Response: It was a mistake. Here we mean 'the amount of carbon uptake in the ocean south of 60'. We have revised it.

4. Lines 76-77: "Therefore, the direction of the sea-air CO_2 transfer is mainly regulated by the oceanic pCO_2" – this statement needs a reference

Response: We have added the references needed.

5. Line 84:"The SOM analysis, based on neural network (NN), a type of artificial neural network" – the second part (based on neural network) can be removed

Response: It has been removed.

6. Line 117: "Salinity records the physical processes" – When I read this sentence I also think of larger scale circulation and mixing in the context of physical processes, whereas this statement links to the follow-up discussion about brine rejection. Maybe a different term would be more appropriate.

Response: It has been revised.

7. Line 130: How was the interpolation done?

Response: We gridded the chlorophyll-a data from Modis according the cruise track.

8. Lines 133-136: "The mixed layer links the atmosphere to the deep ocean and plays a critical role in climate variability. Very few studies have emphasized the importance of accounting for the vertical mixing through the mixed layer depth" – Firstly, I disagree. Several studies have emphasized the importance of vertical mixing of carbon (but also nutrients, etc) through the mixed layer. Secondly, I caution the authors to mention the role in climate variability here. Their study does not resolve the necessary timescales to discuss either seasonal or interannual or decadal (whatever variability the authors refer to) variability.

Response: We have made the correction and have removed the mention about the role in climate variability since in our study it didn't relate to that.

9. Lines 154-155 'SOM based multiple non-linear regression' – This must have been a mistake or typo here, since the SOM (unlike e.g. a back propagation network) does not perform a regression (also not a non-linear one). Instead the SOM clusters data based on similar environmental conditions.

Response: Yes, we agree the reviewer's suggestion and have removed 'multiple non-linear regression'.

10. Lines 194-195: "until the neural network sufficiently represents the nonlinear interdependence of proxy parameters used in training." – how is this judged? When do you know that its sufficient? I suppose this is judged by the number of SOM iterations, but how is set?

Response: Because SOM analysis is a powerful technique to estimate pCO_2 from among the non-linear relationships of the parameters (Telszewski et al., 2009;), actually, we presumed the nonlinear interdependence of proxy parameters are sufficiently represented after the training procedure. Also, we used the som_make() function in the SOM toolbox for training data. Thus, we updated the sentence accordingly.

11. Line 215: "I could not figure out where the factor 30.8*10-4 comes from? Please explain in the text

Response: The factor is induced according to the simplification of the equation. We have added the explanation in the text.

12. Line 264: "robustly divided" – I caution the authors here: How can you be sure the division is "robust"? Have you done any test that would proof robustness?

Response: Three regions are divided according to the distribution of oceanic $p\mathrm{CO}_2$. From the distribution of $p\mathrm{CO}_2$ as shown in Fig.2-a there are three ranges. One is from 291.98 μatm to 379.31 μatm, the second is from 200 to 310μatm and the third is below 200μatm. We roughly divided the study region according to the three ranges of $p\mathrm{CO}_2$ and the range of the depth of water in the Prydz Bay region. It was a mistake to use the word 'robustly'.

13. Lines 281-282: "region atmospheric $p\mathrm{CO}_2$ was stable from 374.6μatm to 387.8μatm" That is a difference of 13μatm – I would not call this stable at all! I suppose this difference is largely the result of sea level pressure variability and relative humidity in the surface layer, hence it would be interesting to see the molar fractions (in ppm) for comparison if available.

Response: We don't have sea level pressure data and relative humidity in the surface layer. We have revised this sentence and removed 'stable'.

14. Line 285: "biological consume" – should be "biological uptake"

Response: It has been revised.

15. Line 318-319:"for a same period" – This would be important information. Furthermore, have you considered ARGO biogeochemistry floats from the SOCCOM array? They are deployed since 2013 and may add some additional independent estimate. This might however be beyond this manuscript.

Response: Thanks for letting us know the SOCCOM. We have searched from SOCCOM but we can't find dataset useful for our study. However SOCCOM is a helpful website and we will turn to it when we other analyses in the Southern Ocean next time.

16. Figure 4b: It would be easier visible if x-axis and y

Response: We have changed the x-axis and y to be the same range.

Responses to review2:

General comments

The manuscript 'variation of Summer Oceanic pCO$_2$ and Carbon Sink in the Prydz Bay Using SOM Analysis Approach' by Suqing Xu et al. presents their cruise data plus its analysis regarding oceanic and atmospheric pCO$_2$ and the related air-sea pCO$_2$ flux. The results can potentially be of interest to readers interested in the Southern Ocean carbon cycling, and its variability in time and space. It also provides an opportunity to the authors to show a practical example of the application of SOM in biogeochemistry. In order for the manuscript to be appreciated by the biogeochemical community, the authors should provide a better description of its relevance and importance for the greater Southern Ocean. S I am not an expert on SOM or neural networks, I cannot judge the methodology on that method in detail. I should however be able to understand what is presented in section 2.2. and I find this difficult at times. Several times mention is made of methods (like 'a linear method' or 'Linear regression extrapolation method') without further information on what is done: This makes reproducibility of the work without consulting the authors impossible. Besides that, I unfortunately often find the language to be confusing/imprecise, and therefore recommend professional English language checking before resubmitting. The language made it more difficult for me to judge the value of the manuscript, and I expect I can provide a more in-depth review after the language is improved. The manuscript would also improve if it were shortened as compared to the current version, as there is enough space to increase the information density in the manuscript in my opinion.

Specific comments

1. The introduction

   The introduction thoroughly describes the geographic setting of the Prydy Bay. I appreciate this, but it makes the introduction unbalanced as the questions 'why is this study of relevance' and 'what is new' are only covered by a few sentences. The authors describe the issue that the manuscript wants to address, namely the sparse spatiotemporal coverage of the Southern Ocean (SO) carbon cycle. They also tell the reader that they address the issue using the SOM approach. However, to what extent does research on the Prydz Bay support our understanding of the SO carbon cycle? On page 2, line 38-39 it is mentioned that the Prydz Bay is the third largest embayment in the Antarctic continent. No other reasons are given for the study of in specific this bay: What makes this bay (potentially) important for the SO carbon cycle even though it is small as compared to the total surface area of the SO? To what extent is this Bay representative for the SO as a whole (or just other parts of the SO),i.e. do the authors think their approach or data are useful for and representative of other areas in the SO? Why was the month February chosen to do the cruise?

   Response: The Prydz Bay region is the third largest embayment in the Antarctic continent and one of the source regions of Antarctic Bottom water (AABW) as well as the Weddell Sea and the Ross Sea (Jacobs and Georgi,1977; Yabuki et al., 2006). Studies have reported that Prydz Bay is a strong carbon sink in the austral summer (Gibsonab and Trullb, 1999; Gao et al., 2008; Roden et al., 2013). It is important to study the carbon cycle in the Prydz Bay. We have revised this part and added the information. The Prydz bay is part of the SO. SOM has been applied to simulate oceanic pCO$_2$ to overcome a complex relationship among the biogeochemical and physical conditions. We chose the beginning of February to early March because we had the in situ measurements during that time.

In the first sentence, it is mentioned that the SO is important for anthropogenic CO_2 uptake. The authors cannot distinguish between natural and anthropogenic carbon fluxes based on their measurements: Some sentences should be added to describe that the SO is a natural source of carbon to the atmosphere, but a sink for anthropogenic carbon – and that both are highly variable but creating a net sink for total carbon over the past decades. Here an argument could be made for their own study and cruise, which aims to reduce the spatiotemporal sparsity of the data and get a better understanding of the variability of the contemporary pCO$_2$ and its driving mechanisms. The authors call the Bay a sink at several instance (for example P3, L101 and P5, L125): Some numbers from previous studies should be given to support the statement that the Bay as a whole is a sink for carbon before presenting your own results.

Response: Sentences have been added to describe the SO on its role for carbon dioxide. About our study and cruise, we have added the argument. Recently studies have shown that there is a strong carbon sink in Prydz Bay especially in summer and we have added the references to support the statement.

In Figure1, an inset could be added to visualize the location of Fig.1 on the Antarctic continent.

Response: For Fig.1, we have added an inset to show the location of the Prydz Bay in the Antarctic continent.

P3,L64-66: How does a marine ecosystem interact with the physical environment to make it complicated to study pCO$_2$? Clarify your statement, as it currently is imprecise.

Response: We have revised this sentence. Here we mean due to the special physical environment and complicated ecosystem, it is difficult to study the spatiotemporal variation of pCO$_2$.

When describing the methods, clarify that in situ data from the cruise are combined with remotely sensed data to arrive at a gridded product.

Response: We have revised to clarify that in situ data from the cruise are combined with remotely sensed data.

2.1 In situ data

Here the authors present how they took their underway measurements and present them in Fig.2. The first time I read this section, I missed a good structure: The section starts with an explanation of the cruise and instruments used (until line 115). Then, the following paragraphs came to me as a bit of a surprise. One could help the reader find a better flow through the text by explaining that there are several processes/water characteristics that can influence the pCO$_2$ flux (which is the topic of this study). Then, the sea ice paragraph(lines 116-120), the information on the SSS and SST collection (lines 132-end of section) come more naturally. It is important to defend why specifically these proxies/data are used to do your study (create a gridded pCO$_2$ map). Don't forget to start the title with a capital letter i. It is unclear tome whether the results presented in Fig.2 are 4-week mean results or how they are calculated from the 4 cruise legs: Add more information to both the caption and the text.

Response: The results presented in Fig.2 are the data along the track cruise when R/V Xuelong sailed from east to west from the beginning of February to early March. It has been added in the caption and the text. We have added the information to explain some processes that can influence the *p*CO_2 distribution in the text.

2.2 SOM method and input variables

This section is generally hard to follow, maybe partly because I am not familiar with SOM. It should be improved so that also people new to SOM are able to understand and appreciate what you have done. Which 'environmental parameters' and which 'observational dataset's (Fig.3) are used? Lines 205-220 (or even up to 228) could be moved up in order to introduce the reader earlier to the datasets. Then the authors can explain what they are used for and how.

Response: Thanks for the suggestion. We have reconstructed this section and make it more clear about the 'environmental parameters' and 'observational datasets ' in the text. We have also revised the sentence about SOM method to make it easier to be understood.

2.3 Validation of SOM derived oceanic *p*CO_2

This section raises a lot of questions from my side. To what extent is SOCAT comparable to your data? Are the data both summer data? Why do you talk about assimilating several years together, but then only take 2015 from SOCAT (line 239)? Could you maybe compare your data to a model estimate of *p*CO_2 for this region? Lines 232-235: How is the equilibrium between atmospheric and surface ocean *p*CO_2, do you mean *p*CO_2-disequilibrium? Why do you describe this if you did not apply this method after all?

Response: We use dataset from SOCAT for the same period, which is February 2015. The dataset from SOCAT for validation as shown in Fig4-a. We prefer in situ measurements to model output to validate our results.We have removed line 232-238. Line 232-238 was a discussion and we think it didn't relate to the text.

2.4 Carbon uptake in the Prydz Bay

This section is quite clear to me: You have combined wind speed data and your *p*CO_2 measurements to arrive at a flux using Eq 2. However, you should clarify 1) where you used a 'scaling factor' (P10, L247-248) (in Eq. 2?), and 2) that that used your SOM-based *p*CO_2 product to calculate *p*CO_2 in Eq.2 (did you?). In addition, you write that the transfer velocity is a function of wind speed and temperature (Line 245) and then you write about a gas transfer rate (Line 248) (=transfer velocity?) which you apply a scaling factor to. I am left with the question which gas transfer rate or velocity you have used / how you calculated it.

Response: The original Eq.2 was a simplified equation considering the unit conversion factor. Now we have added the original sea-air CO_2 flux equation in the text and we have revised this part and added some information.

3.1 the distribution of underway measurements

Here you present your underway measurements for three areas. On what basis did you divide the Prydz Bay in these subregions? You write the division is 'robust' (P11, L264): Did you test what effect the choice of your division has on your results? It would be helpful to the reader if you added a plot figure with the subdivision of the Prydz Bay into its three regions. Add units to all numbers (especially salinity lacks the psu unit throughout this section). I assume you are describing the results that are visualized in Fig 2 in this section: you should make reference to it if this is the case. Throughout the text of this section, you should be more precise on whether the values are regional means, 4-week means, and how you calculated this (refer to the methods).When you say decrease or increase (like P12, L291), it is not always clear to me whether it decreases/increases in time or space or whether the mean is lower or higher than in the neighboring sub-region. This causes for example confusion when SST's 'vary sharply' (L293) but 'decreased slightly' just the sentence above (L291). The readability of this section may improve by summarizing your main results in a table. A sentence should be added either here on the methods where the relationship between chlorophyll-a (as remotely observed) and biological productivity is stated.

Response: Three regions are divided according to the distribution of oceanic $p\mathrm{CO}_2$ and depth of water. From the distribution of $p\mathrm{CO}_2$ as shown in Fig.2-a and Table.2 there are three ranges. One is from about 300μatm to 380μatm, the second is from 200μatm to 350μatm and the third is below 250μatm. We roughly divided the study region according to the three ranges of $p\mathrm{CO}_2$ and the range of the depth of water in the Prydz Bay region. It was a mistake to use the word 'robustly'. We have made the change to the text.

We have added units to all numbers. We have added the subdivision lines on Figures. 5.

We have added the reference to Fig 2 in this section.

Section 3.1 was about the in-situ measurements and the average values we discussed were regional mean. We have added the information in the text to avoid the confusion about the numbers. A table was added to the text summarizing our main results. A sentence has been added here about the relationship between chlorophyll-a and biological productivity.

3.2 Quality and maps of SOM-derived oceanic $p\mathrm{CO}_2$

You compare your results to SOCAT and calculate the RMSE. Could you also provide the R2 of the best-fit line (red line in Fig. 4b)? You say your RMSE is consistent but not as good as most of the neuron methods. Do you mean it is on the high side of the accuracies previously reported, or why is it not as good? Could you calculate/estimate how many extra data points you would need to gain an improved precision of your SOM approach? You could probably comment on the limited amount of data that retrieving more data is not realistic with the resources and time available. SOCAT is not perfect either: A comment on its limited overlap with your study area would be appropriate here. It is surprising that the SOM estimate is generally higher than the SOCAT one, as SOCAT does not cover the low- $p\mathrm{CO}_2$ area towards the south. Did you sample your SOM-derived $p\mathrm{CO}_2$ dataset on the SOCAT locations, or did you compare all SOCAT in the area to all your data points in Fig. 4b? The first would probably be a fairer comparison and provide a better outcome as well. Fig.4a could be plotted in the same way as Fig.2 to make it easier for the reader to compare the spatial coverage.

Response: Our RMSE is on the high side of the accuracies previously reported and the correlation coefficient has been added in the text. There are two reasons accounting for the precision. One is the limited spatial coverage of the in situ measurements to be labeled in SOM method. Increasing the spatial coverage of the labeling data will help to increase the precision of SOM derived oceanic $p\mathrm{CO}_2$. The other one is the dataset from SOCAT is not sufficient neither for space overlap nor for time overlap. The best way to get an improved precision of the SOM approach is to have a full coverage measurement in the study area. In our study, we selected the SOM derived oceanic $p\mathrm{CO}_2$ according to the location of the datasets from SOCAT for validation. As mentioned in the text, SOM derived $p\mathrm{CO}_2$ is generally lower than the SOCAT one. We have plotted Fig.4a as Fig.2.

3.3 Spatial and temporal distributions of SOM-derived pCO_2

Here I expect the presentation of your main result: the pCO_2 maps of Figure 6. However, the text mostly describes the sea ice situation of the region: Why is this done here? Maybe a different title would be more appropriate? If sea ice is a main driving factor for pCO_2, this should be argued using the results. If the authors could add regional sub-division lines on the maps in Fig. 6, it might be easier to argue for the chosen sub-division (i.e. Shelf region, etc).

Response: We agreed with the reviewer and have revised this section. This section is mainly about the result of SOM derived pCO_2. We have presented the spatial and temporal distribution of SOM derived pCO_2. We have added regional sub-division lines on the maps.

3.4 Carbon uptake in Prydz Bay

This section is quite clear, although it would be good to clarify when mean values are reported, and whether they are regional means or temporal means, or both. From the figure on page 17 (which has no number?) it is hard to read the pCO_2 changes: one could either present it as a table, or adjust the y-axis range. Please make sure the figure is suitable for the color blind (and check this throughout the manuscript): Use for example different shapes for the three different lines in the upper graph, and add shapes in the lower one.

Response: We have changed the figure to be a table and we have made the revised in the text.

Supplementary information

The text at the start of the SI is already used in the main text, I do not see the need to provide it twice, and would recommend to remove it from the SI.

Technical corrections

I made an effort to pick out the most important language issues. However, as recommended in the general comments, I would strongly advise the authors to revise their language throughout the manuscript and to have it checked before resubmitting.

1. Try to prevent the use of the word 'it' throughout the manuscript: replace by the actual subject of the sentence.

   Response: We have made the changes in the text.

2. Caption of Fig.1: replace 'The circulations in the ' by 'The ocean circulation in the '. Replace sentence 'The weekly sea ice extents for our study periods were overlapped on the cruise.' By 'During the 4-week cruise, the sea ice extent varied as indicated by the contoured white areas:' and replace 'the white shadow' by a fourth contoured area.

   Response: It has been replaced.

3. Check all figures on their suitability for color-blind people

   Response: We have checked all the figures.

4. P2, L33: replace 'of reducing anthropogenic CO_2 in the atmosphere' with 'in regulating atmospheric carbon and acting as a net sink for anthropogenic carbon' or similar.

   Response: It has been replaced.

5. P2, L35: replace ‘this status derives’ by ‘This uncertainty comes’
   Response: It has been replaced.

6. P2,L36: replace ‘for’ with ‘because of’
   Response: It has been replaced.

7. P2, L38: move ‘lying in the Indian Ocean section’ to the next sentence and replace ‘lying’ by ‘situated’
   Response: It has been moved and replaced.
8. P2, L39-40: move ‘With Cape Darnley … to the east’ to the end of the sentence or rephrase whole sentence, try to use the main verb as early as possible in a sentence
   Response: It has been moved and rephrased.
9. P2, L41: replace ‘varies’ by ‘increases’ (or does it go up and down?)
   Response: It has been replaced.

10. P3, L51-52: Add ‘the’: ‘The Fram Bank and the Four Ladies Bank’
    Response: It has been added.

11. P3, L52: a spatial barrier for
    Response: It has been revised.
12. P3, L54: replace ‘part of it’ by ‘partly’
    Response: It has been replaced.

13. P3, L63-64: rephrase sentence to clarify the sequence of events
    Response: It has been rephrased.

14. P2,L67: the importance for what? Replace ‘carbon cycle’ by ‘carbon cycling’. This relates to comment 1 as well: how does studying the Prydz Bay relate to the SO carbon cycle?
    Response: We have added the importance of study carbon cycling in the Prydz Bay and added the information about the Prydz Bay related to the SO carbon cycle in the introduction section.

15. P3, L69: use present tense where possible: ‘is’
    Response: It has been replaced.

16. P3, L72: remove first word ‘the’
    Response: It has been removed.

17. P3,L77: Add ‘A’ before ‘linear’. Clarify that it was not you doing this by adding ‘In earlier studies, …’
    Response: It has been revised.

18. P4, L78: What is a big scale? The entire Prydz Bay, the SO?
    Response: We have revised and made it clear to be ‘that alinear regression extrapolation method has been applied to expand the cruise data to study the carbon cycle in the Southern

Ocean'.

19. P4, L79: Start a new sentence at 'however'. Simplicity can be a good thing: why is calculating pCO$_2$ based on SST and CHL insufficient? How do you know what controlling factors to select?
Response: There are two opposing processes primarily govern CO$_2$ chemistry in seawater: sinking of biological products from the photic zone to deep-ocean regimes (i.e., the biological pump), and upward transport by upwelling deep waters of CO$_2$ and nutrients formed by the decomposition of biological debris (i.e., the physical pump). It is not sufficient to simulate oceanic pCO$_2$ based on SST and CHL in previous studies, of which the RMSE tended to be high. From our previous researches and other studies we chose SST, CHL, MLD and SSS to be the controlling factors and we have added the information in the text.

20. P4, L83: remove 'the' before 'February'
Response: It has been removed.

21. P4, L84: Is NN a type of neural network? The acronym NN is not used anywhere else in the manuscript – so not need to define it. What makes it artificial?
Response: NN is an abbreviation for neural network. Here artificial means artificial intelligence.

22. P4, L85: Remove 'been'
Response: It has been removed.

23. P4, L88: Add 'and' before 'chlorophyll'
Response: It has been added.

24. P4,L92: Remove 'been' and replace 'a' before spatial-temporal by 'the'
Response: It has been removed.

25. P4, L97: Add the word 'cruise' after 'CHINARE'. Do the same on P4, L108.
Response: They have been revised.

26. P4, L98: replace 'to the early of March' with 'to early March'. Check general fluency of lines 97-99.
Response: It has been replaced.

27. P4, L99: replace 'is show' by 'are shown'
Response: It has been replaced.

28. P4, L101: here the authors suddenly discuss carbon absorption: the readers have not learned before that this area is considered to be a sink for carbon, so it would be could to introduce the reader to that earlier in the introduction
Response: It has been revised and we have added the information that the Prydz Bay is a carbon sink in the introduction.

29. P4,L102: Replace ‘followed’ by ‘follows’
    Response: It has been replaced.

30. P4, L104: Add ‘, and’ and remove ‘.’
    Response: It has been revised.

31. P4, L108: ‘at the beginning of February 2015’, did the cruise not extend into March? Why ‘beginning’?
    Response: It has been revised. The cruise was from the beginning of February to early March.

32. P5, L115: replace ‘$p\mathrm{CO_2}$ in atmosphere’ by ‘atmospheric $p\mathrm{CO_2}$’. Check also that each time you use the word $p\mathrm{CO_2}$, that you use an italicized letter p (also in captions, and axes titles)
    Response: It has been revised.

33. P5, L116/117: Replace ‘in polar region’ by ‘in polar regions’
    Response: It has been replaced.

34. P5, L117: Move sentence ‘Salinity records the physical processes’ to later in the paragraph, because you first need to explain what salinity has to do with sea ice. It would also fit to explain to the reader why this is all relevant for a study of $p\mathrm{CO_2}$.
    Response: It has been revised.

35. P5, L117-118: Replace ‘During freezing, salt is excluded … [] … brine rejection’ with ‘During freezing, brine is rejected from ice, thereby increasing sea surface salinity’.
    Response: It has been revised.

36. P5, L119: replace ‘to dilute’ with ‘thereby diluting’
    Response: It has been replaced.

37. P5, L125: Remove ‘clearly’
    Response: It has been removed.

38. P5, L127-128: ‘the active biological process’: Do you mean photosynthesis?
    Response: Yes and we have added information about the relationship between chlorophyll-a and biological productivity in the text.

39. P5, L128-129: Explain the relationship between chlorophyll-a and biological productivity before you directly connect them and the consecutive effect on $p\mathrm{CO_2}$ in this sentence.
    Response:

40. P5, L129: Clarify that you used remote sensing data, and provide the reader with uncertainties associated with this method. Be consistent writing Modis either as Modis or MODIS.
    Response: We have clarified that we used remote sensing data from MODIS. The uncertainty

associated was mentioned in the last paragraph in section 2.2.

41. P5, L130: Replace link by appropriate reference.
    Response: We prefer the link to show where the data comes from.

42. P5, L138-139: This sentence seems to repeat lines 121-122 on this page.
    Response: It has been deleted.

43. P5/6, L139-141: Rephrase sentence to make clear to the reader that there are two main methods in use, and what the advantages are of the ‘difference criterion’ method in the SO.
    Response: It has been rephrased.

44. P6, L141: Add ‘therefore’ between ‘we’ and ‘calculated’
    Response: It has been added.

45. P6, L142: Replace ‘the’ with ‘on’
    Response: It has been replaced.

46. P6, L142-143: ‘of with …’ Do you mean ‘of which’? I do not understand this sentence, sorry.
    Response: Yes, we mean ‘of which’.

47. P6, L143-144: Why where the data gridded? They were point data from the CTD taken along the track, so why where they not already on the right spatial and temporal ‘resolution’ (do you mean interval?)?
    Response: Yes, we gridded the point data from the CTD taken along the track in interval and we have revised the sentence.

48. P6, L150-151: Start with a capital letter t. Some words have disappeared from the caption.
    Response: It has been revised.

49. P7, L161: Replace ‘dimension’ by ‘dimensional’
    Response: It has been replaced.

50. P7, L 163: ‘Input variables’, how do these relate to the boxes in Fig.3?’as a vector’ is more fluent than ‘in a vector form’
    Response: The input variables related to the environmental parameters in Fig.3. We have made it clear the input variables and the environmental parameters. We have also changed to be ‘as a vector’.

51. P8, L173: did not all your underway measurements include measurement of $p\mathrm{CO}_2$?
    Response: The underway measurements included measurement of $p\mathrm{CO}_2$. Here we mean: for the training process, the input environmental parameters are those from satellite and model data of 0.1 resolution. However, the measurement of $p\mathrm{CO}_2$ was along the cruise track and it has a spatiotemporal limitation compared to satellite data.

52. P8, L178: Why did you quantify skewness and what did you do with the results? Is taking the logarithm an accepted method to improve the N coverage? Why does the coverage increase when taking the log?
53. P8, L186: Why is this not done for SST and SSS?

Response to No.52&53: In table 1 all values are absolute values of the four proxies to show the value range. For the skewness and the N coverage percentage, the normalized data are shown in parenthesis. According to the change of skewness and N coverage percentage we found out only MLD and Chla data needed to be normalized for both the training and labeling dataset. Since we used Euclidean distance function to select the winner neuron and it depends on the data-value range of each proxy. The normalization for MLD and Chla dataset is to avoid weighting issue raised from the different magnitude among the variables.

In section 2.1 we have discussed the four proxies which will affect the distribution of $p\mathrm{CO}_2$ in the surface sea water. The dissolution of CO_2 into water is mainly affected by temperature and pressure of water. The variation of salinity has little effect on the dissolution of CO_2. However the sea ice changed quickly in the study region and we chose salinity to be a proxy to simulate $p\mathrm{CO}_2$. Moreover, in the region where local biology activities are active, $p\mathrm{CO}_2$ will be affect strongly by photosynthesis. The mixed layer depth will prevent the upward mixing of nutrients and limits the biological production therefore we chose MLD as another proxy to simulate $p\mathrm{CO}_2$. Sea surface height and sea level pressure are not major factors to the distribution of oceanic $p\mathrm{CO}_2$. Wind speed is vital for the sea-air gas exchange and it is included in the air-sea flux equation.

54. P9, L198: Add 'part of the' between 'second' and 'process'. Also, it is either each neuron or all neurons (i.e. is it plural or singular here?)

    Response: It has been added and corrected to be 'neuron'.

55. P9,L213: What is meant with '8-d'? 8 dimensions, 8 days? If 8 days, why not 7 if used as weekly data?

    Response: '8-d' meant 8 days here. Our study period was from the beginning of February to March 4. When we used 8 days as weekly it was proper to cover the study period.

56. P10, L243: Replace 'by two items' with 'using $p\mathrm{CO}_2$ and the transfer velocity across the air-sea interface' or something similar.

    Response: It has been replaced.

57. P10, L246: Replace 'delta' with '△'

    Response: It has been replaced.

58. P10, L247: What scaling factor are you talking about here? Is it in Wq.2?

    Response: The scaling factor for the gas transfer rate is 0.251. It was not shown in Eq.2 because Eq.2 is a simplified equation taking into account the unit conversion factor. We have revised this part to make it clear.

59. P10, L251: Check that equation has one format/font and denote units in []-brackets.
    Response: It has been revised.

60. P10, L252: Check superscripts of $p\mathrm{CO_2}$-air and $p\mathrm{CO_2}$_sea, also add ‘and’ before $p\mathrm{CO_2}$_sea and end the sentence with ‘respectively’
    Response: It has been checked.

61. P10, L256: I am again confused by the use of the word regridding, your are working with sample data– why do you regrid? You mean you gridded the data from the point measurements you had of atmospheric $p\mathrm{CO_2}$? What linear method did you use?
    Response: The atmospheric $p\mathrm{CO_2}$ was of the cruise track. When we got the SOM derived oceanic pCO2 it was of 0.1*0.1 resolution. In order to calculate the air-sea flux we need to extrapolate the atmospheric $p\mathrm{CO_2}$ to be the same 0.1*0.1 resolution. We used linear method.

62. P10, L258-259: Do you mean you integrated the gridded flux over the area of Prydz Bay, taking into account the ice-free area only? How did you take ice into account?
    Response: We have added the information to the text. The sea-air flux was calculated according to the proportion of ice-free area.

63. P11, L267: No need to use the acronym AD if you only use it once
    Response: It has been revised.

64. P12, L300: What is formed here? The subject of the sentence is the Shelf region, but a regions cannot be formed by modification of water.
    Response: It was a mistake and we have changed the subject to be ‘water inside the Shelf region’.

65. P12, L305-306: If the region was ice-free, Fig.5 cannot be correct?
    Response: Fig.5 is correct and the ice shown in Fig.5 is permanent ice. We have revised the sentenced to be ‘the most least ice-covered’.

66. P12, L314-315: When and where does the biological pump become the dominant factor setting the distribution of $p\mathrm{CO_2}$? How do you know this is the main contributor to the $p\mathrm{CO_2}$ variations?
    Response: The low oceanic $p\mathrm{CO_2}$ was consistent with the high chlorophyll value in the Shelf region. For four weeks biological pump was the dominant factor setting the distribution of $p\mathrm{CO_2}$. In the Shelf region other factors didn’t show such pattern with oceanic $p\mathrm{CO_2}$.

67. P16, L371: What indicators did you use to conclude that the stability of the water was weak?
    Response: The original sentence is not proper here. We have removed this sentence.

68. P16, L377: flew? Please rewrite this sentence.
    Response: It was a mistake. It should be ‘flowing’ and we have corrected it.

69. P18, L395: 10^{12}gram=Tg

Response: It has been revised.

70. P18, L400: Please provide references to this statement and mention it earlier in the manuscript.
    Response: The references have been added and we have added the information in the introduction.

71. P18, L408-410: So does the region take up more carbon than on average in the ocean? I.e., is it a relatively large sink as compared to its area?
    Response: Yes, this region takes up more carbon than on average in the ocean. Though small area, it is a relatively large sink. Taking into account the Prydz Bay is one of the resources of AABW (Antarctic Bottom Water), large amount uptake of atmospheric CO_2 may have an effect on the ocean acidification in the long run.

Variation of Summer Oceanic $p\mathrm{CO_2}$ and Carbon Sink in the Prydz Bay Using SOM Analysis Approach

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Abstract

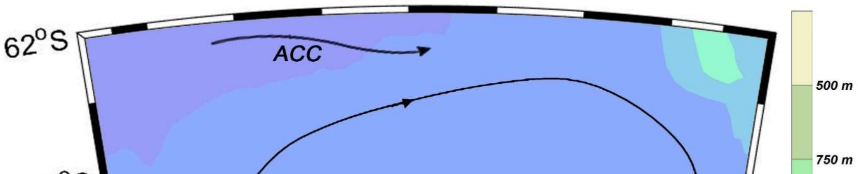
This study applies a neural network technique to produce maps of oceanic surface $p\mathrm{CO_2}$ in the Prydz Bay in the Southern Ocean on a weekly 0.1° longitude · 0.1° latitude~~0.1 longitude · 0.1 latitude~~ grid based on in-situ measurements obtained during the 31~~th~~st CHINARE cruise from February to early March of 2015~~for February 2015~~. The study area was divided into three regions, namely, the Open-ocean region, Sea-ice region and Shelf region. The distribution of oceanic $p\mathrm{CO_2}$ was mainly affected by physical processes in the Open-ocean region, where mixing and upwelling ~~became~~ were the main controls. ~~While i~~In the Sea-ice region, oceanic $p\mathrm{CO_2}$ changed sharply due to the strong change in~~of~~ seasonal ice. ~~For~~ In the Shelf region, biological factors w~~as~~ere the main control. The weekly oceanic $p\mathrm{CO_2}$ was estimated using a self-organizing map (SOM) ~~by~~ with four proxy parameters (Sea Surface Temperature, Chlorophyll a concentration, Mixed Layer Depth, and Sea Surface Salinity) to overcome thecomplex relationship betweenthe biogeochemical and physical conditions in the Prydz Bay region.~~resolve the nonlinear relationships under complicated biogeochemical conditions in Prydz Bay region.~~ The reconstructed oceanic $p\mathrm{CO_2}$ data coincide~~s~~ well with the in-situ investigated $p\mathrm{CO_2}$ from SOCAT, ~~in the~~with a root-mean-square error of 22.14 µatm. The Prydz Bay was mainly a strong $\mathrm{CO_2}$ sink in February 2015, with a monthly averaged uptake of 23.57±6.36~~18.7±4.93~~ TgC. The oceanic $\mathrm{CO_2}$ sink is pronounced in the Shelf region due to its lowest oceanic $p\mathrm{CO_2}$ and~~with~~ peak biological production. ~~Strong potential anthropogenic $\mathrm{CO_2}$ uptake in the Shelf region will~~

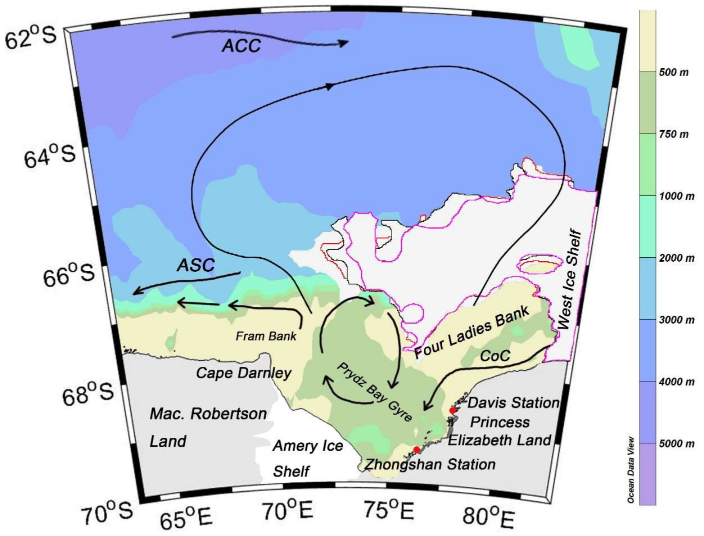
~~enhance the acidification in the deep water of Prydz Bay and affect the deep ocean acidification in the long run since it contributes to the formation of Antarctic bottom water.~~

1 Introduction

The amount of carbon uptake occurring in the ocean south of 60°S duringthe transport of CO$_2$ to or from the atmosphere is still uncertain despite its importance in regulating atmospheric carbon and acting as a net sink for anthropogenic carbon~~The role of the ocean south of 60°S in the transport of CO$_2$ to or from the atmosphere is still uncertain despite of its importance of reducing anthropogenic CO$_2$ in the atmosphere~~ (Sweeney et al., 2000, 2002; Morrison et al., 2001; Sabine et al., 2004; Metzl et al., 2006; Takahashi et al., 2012). This uncertainty arisesfrom both the strong seasonal and spatial variations that occur around Antarctica and the difficulty of obtaining field measurements in the region because of its hostile weather and remoteness.~~This status derives from both the strong seasonal and spatial variations that occur around Antarctica, and the difficulty of field measurements in the region for its hostile weather and remoteness~~.

Following the Weddell and Ross seas, the Prydz Bay is the third-largest embayment in the Antarctic continent. Situated in the Indian Ocean section, the Prydz Bay is located close to the Amery Ice Shelf to the southwest and the West Ice Shelf to the northeast, with Cape Darnley to the west and the Zhongshan and Davis stations to the east~~, lying in the Indian Ocean section, is the third largest embayment in the Antarctic continent. With Cape Darnley to the west and the Zhongshan Station and Davis Station to the east, Prydz Bay is close to the Amery Ice Shelf to the southwest and the West Ice Shelf to the northeast~~ (Fig. 1). In this region, ~~W~~water depth ~~varies~~ increases sharply northward from 200 m to 3000 m.





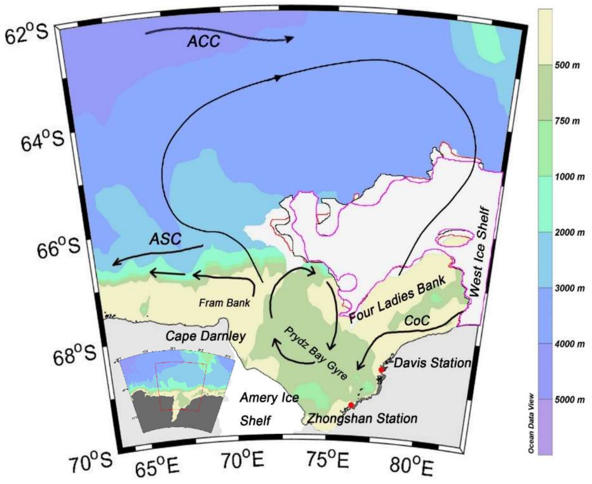


Fig. 1 Ocean circulations in the Prydz Bay derived from Roden et al. (2013) , Sun et al. (2013), Wu et al. (2017). ASC: Antarctic Slope Current; CoC: Antarctic Coastal Current; ACC: Antarctic Circumpolar Current. During the 4-week cruise, the sea ice extent varied as indicated by the contoured white areas: the pink line is for week-1(20150202-20150209), the black line is for week-2 (20150210-20150217), the red line is for the

week-3 (20150218-20150225) and a fourth contoured area is for week-4 (20150226-20150305).~~The circulations in the Prydz Bay derived from Roden et al. (2013), Sun et al. (2013), Wu et al. (2017). ASC: Antarctic Slope Current; CoC: Antarctic Coastal Current; ACC: Antarctic Circumpolar Current. The weekly sea ice extents for our study periods were overlapped on the cruise. the pink line is for week-1(20150202-20150209), the black line is for week-2 (20150210-20150217), the red line is for the week-3 (20150218-20150225) and the white shadow is for week-4 (20150226-20150305).~~

The inner continental shelf is dominated by the Amery Depression, which mostly ranges in depth from 600 to 700 m~~is mostly 600 to 700 m deep~~. The depression is bordered by two shallow banks (<200 m): the Fram Bank and the Four Ladies Bank, which form a spatial barrier for water exchange with the outer oceanic water~~forming a spatial barrier to water exchange with the outer oceanic water~~ (Smith and Trégure, 1994). The Antarctic Coastal Current (CoC) flows westward, bringing in cold waters from the east. When the CoC~~it~~ reaches the shallow Fram Bank, it turns north and then partly~~ of it~~ flows westward, while ~~part ~~some of it turns eastward, back to the inner shelf, resulting in the clockwise~~-~~-rotating Prydz Gyre (see Fig.1). The circulation to the north of the bay is characterized by a large cyclonic gyre, extending from within the bay to the Antarctic Divergence at ~~about ~~approximately 63°S (Nunes Vaz and Lennon, 1996; Middleton and Humphries, 1989; Smith et al., 1984; Roden et al., 2013; Wu et al., 2017~~Nunes Vaz and Lennon, 1996; Middleton and Humphries, 1989; Smith et al., 1984; Roden et al., 2013; Wu et al., 2017~~). The inflow of this large gyre hugs the eastern rim of the bay~~,~~ and favours the onshore intrusions of warmer modified Circumpolar Deep Water ~~(mCDW)~~ across the continental shelf break (Heil et al., 1996). ~~A w~~Westward flow along the shelf, ~~that ~~which is part of the wind-driven Antarctic Slope Current (ASC), supplies water to the Prydz Bay. ~~In the austral summer, with longer daylight and increased solar radiation, sea surface temperature increases, ice shelf breaks and sea ice melts, resulting in stratification of the water column. Prydz Bay region is host to a marine ecosystem that interacts with the physical environment which makes it complicated to study the spatiotemporal variability and mechanism of oceanic~~ ~~pCO_2.~~

It has been reported that the Prydz Bay is a strong carbon sink, especially in the austral summer~~Despite the importance of carbon cycle in the Southern Ocean, the observations are rather limited to analyze the spatiotemporal variation in the Prydz Bay. The analysis of temporal variability and the spatial distribution mechanism of oceanic~~ ~~pCO_2 in Prydz Bay was limited to cruises or stations~~ (Gibsonab et al., ~~and Trullb~~, 1999; Gao et al., 2008; Roden et al., 2013).

Moreover, studies have shown that the Prydz Bay region is one of the source regions of Antarctic Bottom Water as well as the Weddell and Ross seas(Jacobs and Georgi,1977; Yabukiet al., 2006). It is thus important to study the carbon cycle in the PrydzBay. However, the analysis of the temporal variability and spatial distribution mechanism of oceanic $p\mathrm{CO_2}$ in the Prydz Bay is limited to cruises or stations due to its uniquephysical environment and complicated marine ecosystem (Smith et al., 1984; Nunes Vaz et al., 1996; Liu et al., 2003). To estimate regional sea-air $\mathrm{CO_2}$ fluxes, it is necessary to interpolate between in-situ measurements to obtain ~~the~~ maps of oceanic $p\mathrm{CO_2}$. Such an interpolation approach, however, is still ~~a~~ difficult~~ task because~~, as observations are too sparse ~~in~~ over both time and space to capture the high ~~$p\mathrm{CO_2}$~~ variability in $p\mathrm{CO_2}$. Satellites do not measure $p\mathrm{CO_2}$, but they do provide ~~give~~ access to the parameters related to the processes that control its variability. The seasonal and geographical variability of surface water $p\mathrm{CO_2}$ is indeed much greater than that of atmospheric $p\mathrm{CO_2}$. Therefore, the direction of ~~the~~ sea-air $\mathrm{CO_2}$ transfer is mainly regulated by ~~the~~ oceanic $p\mathrm{CO_2}$~~.~~, and the method of spatially and temporarily interpolating in situ measurements of oceanic $p\mathrm{CO_2}$ has long been used(Takahashi et al., 2002 and 2009; Olsen et al., 2004; Jamet et al., 2007; Chierici et al., 2009). In earlier studies, a linear regression extrapolation method was applied to expand cruise data to study the carbon cycle in the Southern Ocean (Rangama et al., 2005; Chen et al., 2011; Xu et al., 2016).~~Linear regression extrapolation method has been applied to expand the cruise data to a big scale area to study the carbon cycle in the Southern Ocean (Rangama et al., 2005; Chen et al., 2011; Xu et al., 2016),~~ H~~h~~owever, this~~e~~ linear regression relied simply ~~either~~ on either chlorophyll-a (CHL) or ~~on~~ sea surface temperature (SST) parameters. Thus, this method can not sufficiently~~is insufficient to~~ represent all ~~the~~ controlling factors. In this study, we applied self-organizing map (SOM) analysis to expand our observed data sets and estimated the oceanic $p\mathrm{CO_2}$ in the Prydz Bay from February to early March of 2015.~~during the February 2015~~.

The SOM analysis, which is a type of artificial neural network, has been proven to be a useful method for extracting and classifying features in the geosciences, such as trends in (and between) input variables(Gibson et al., 2017; Huang et al., 2017b). ~~The SOM analysis, based on neural network (NN), a type of artificial neural network, has been proved to be a useful method for extracting and classifying features in geoscience (Gibson et al., 2017; Huang et al., 2017b).~~ The SOM uses an unsupervised learning algorithm (i.e., with no need for a priori, empirical or theoretical descriptions of input-output relationships), thus enabling us to identify the relationships between the state variables of the phenomena being analysed, where our understanding of these cannot be fully described using mathematical equations and thus where applications of knowledge-based models are limited (Telszewski et al., 2009). In the field of oceanography, SOM has been applied for the analysis of various properties of the seawater, such as sea surface temperature (Iskandar, 2010; Liu et al., 2006), and chlorophyll concentration (Huang et al., 2017a; Silulwane et al., 2001). In the past decade, SOM has also been applied to produce basin-scale $p\mathrm{CO}_2$ maps, mainly in the North Atlantic and Pacific Ocean, by using different proxy parameters (Lafevre et al., 2005; Friedrich & Oschlies, 2009a, 2009b; Nakaoka et al., 2013; Telszewski et al., 2009; Hales et al., 2012; Zeng et al., 2015; Laruelle et al., 2017). SOM has been proven~~d~~ to be useful ~~to~~for expanding the~~ a~~ spatial-temporal coverage of direct measurements or ~~to ~~for estimat~~e~~ing properties whose satellite observations are technically limited. One of the main benefits of the neural network method over ~~the ~~more traditional techniques is that it provides more accurate representations of highly variable systems of interconnected water properties~~there is more accurate representation of the highly variable system of interconnected water properties~~ (Nakaoka et al., 2013).

We conducted a survey during the 31st CHINARE cruise in the Prydz Bay (Fig. 2).~~During the 31th CHINARE in Prydz Bay, we have conducted a survey on partial pressure of~~ ~~CO_2~~ ~~in oceanic water and atmosphere from the beginning of February to the early of March (data of the cruise track is shown in Fig. 2)~~. This study ~~is ~~aimed to apply the SOM method, combined with remotely sensed data, to reduce the spatiotemporal scarcity of contemporary △$p\mathrm{CO}_2$data and toobtain a better understanding of the capability of carbon absorption in the Prydz Bay from 63°E to 83°E and 64°S to 70°S from February to early March of 2015.~~ to reconstruct the temporal and spatial variability of oceanic~~ ~~$p\mathrm{CO}_2$~~ ~~distribution in Prydz Bay from 63°E to 83°E, 64°S to 70°S and discuss the capability of carbon absorption in February 2015.~~

The paper is organized as follows~~ed~~. Section 2 provides the descriptions of the in ~~-~~situ measurements and~~ the~~ SOM methods. Section 3 presents the analysis and discussion of the results~~.~~, and ~~S~~section 4 presents ~~the ~~a summary of this research.

2 Data and methods

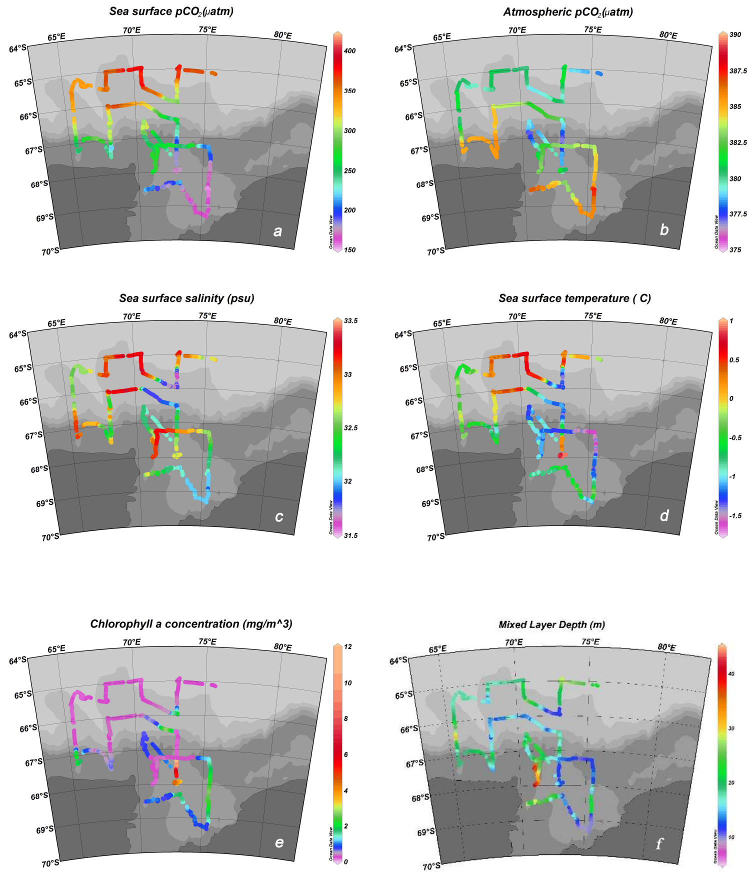
2.1 in situ data

The in situ underway $p\mathrm{CO}_2$ values of marine water and the atmosphere were~~as~~ collected during the 31~~th~~st CHINARE cruise, when the R/V Xuelong sailed from east to west from the beginning of February to early March, 2015 (see Fig.2a, b).~~at the beginning of February 2015 (see Fig.2-a, b).~~ Sea water at a depth of 5 meters ~~underneath~~ beneath the sea surface was pumped continuously to the GO system (GO Flowing $p\mathrm{CO_2}$ system, General Oceanics Inc., Miami FL, USA), and the partial pressure of the sea surface water wa~~i~~s measured by an infrared analyzer (LICOR, USA, Model 7000). The analyzer was calibrated every 2.5-3 h using four standard gases supplied by NOAA's Global Monitoring Division at pressures of 88.82 ppm， 188.36 ppm， 399.47 ppm， 528.92 ppm ~~supplied by NOAA's Global Monitoring Division~~. The accuracy of the measured $p\mathrm{CO_2}$ data is within 2 µatm (Pierrot et al., 2009). ~~The u~~Underway atmospheric $p\mathrm{CO_2}$ ~~in atmosphere was~~were simultaneously collected by the GO system. Due to the biological and physical pumps of carbon cycling in the ocean (Hardman-Mountford et al., 2009; Bates et al., 1998a, 1998b; Barbini et al., 2003; Sweeney, 2002), the key factor controlling its gradient in sea-air levels is the solubility of $\mathrm{CO_2}$. The solubility of $\mathrm{CO_2}$ is affected by temperature and salinity in the water as well as biological activities, such as phytoplankton taking up $\mathrm{CO_2}$ through photosynthesis and organisms releasing $\mathrm{CO_2}$ through respiration (Chen et al., 2011). There are several processes that can influence the distribution of oceanic $p\mathrm{CO_2}$.

Sea ice melt has a significant impact on the local stratification and circulation in polar regions. During freezing, brine is rejected from ice, thereby increasing the sea surface salinity. When ice begins to melt, fresher water is added into the ocean, thereby diluting the ocean water, i.e., reducing its salinity. Changes in salinity thus record physical processes. ~~Salinity records the physical processes. During freezing, salt is excluded from ice, and thus increase the ocean surface salinity. This is so called brine rejection. When ice begins to melt, fresher water is added into the ocean to dilute the ocean water, i.e., reducing the salinity.~~ In this study, we treat salinity as an index for ~~the~~ changes ~~of~~ in sea ice. The underway ~~sea surface temperature~~ SST and conductivity data wa~~s~~ere recorded by a Conductivity-Temperature-Depth sensor (CTD, Seabird SBE 21) along the cruise track. Later, sea surface salinity was calculated ~~according to~~based on the recorded conductivity and temperature data. The distributions of underway SST and SSS are~~were~~ shown in Fig.2 c and d.

In austral summer, when sea ice started to melt, ice algae were released into the seawater, and the amount of living biological species and primary productivity increased; thus, high chlorophyll-a values were observed (Liu et al., 2000; Liu et al., 2003). ~~In p~~Previous studies ~~it~~ ~~has~~have ~~been~~ reported that the summer sink in the Prydz Bay is ~~clearly~~ biologically driven and that the change in pCO$_2$ ~~change~~ is often well- correlated with surface chlorophyll-a concentration (Rubin et al., 1998; Gibsonab et al., 1999; Chen et al., 2011; Xu et al., 2016). ~~When sea ice starts to melt, the active biological process affects oceanic pCO$_2$ significantly (Chen et al., 2011; Xu et al., 2016).~~ The chlorophyll-a value is regarded as an important controlling factor of pCO$_2$. Remote sensing data of chlorophyll-a obtainedfrom MODIS with a resolution of 4 km (http://oceancolor.gsfc.nasa.gov) were interpolated according to the cruise track (Fig.2e).~~Daily Modis chlorophyll-a data of 4 km resolution (http://oceancolor.gsfc.nasa.gov) are interpolated to the observation section and time. The interpolated result along the cruise track is shown in Fig.2e.~~

The ocean mixed layer is characterized as having nearly uniform physical properties throughout the layer, with a gradient in its properties occurring at the bottom of the layer. The mixed layer links the atmosphere to the deep ocean. ~~and plays a critical role in climate variability. Very few~~ Previous studies have emphasized the importance of accounting for the vertical mixing through the mixed layer depth (MLD, Dandonneau, 1995; Lüger et al., 2004). The stability and stratification of this layer prevent the upward mixing of nutrients and limits ~~the~~ biological production, ~~and~~ thus affecting the sea-air CO$_2$ exchange. There are two main methods used to calculate the MLD: one is based on the difference criterion, and one is based on the gradient criterion. Early studies suggested that the MLD values determined in the Southern Ocean using the difference criterion are more stable (Brainerd and Gregg, 1995; Thomson and Fine, 2003).~~The vertical profile of sea water including potential density was measured by a Seabird SBE 11. Comparison of MLD based on the difference and gradient criteria (Brainerd and Gregg, 1995; Thomson and Fine, 2003) suggested that MLD determined using a difference criterion is more stable in the Southern Ocean.~~ Thus, ~~F~~following Dong et al. (2008), we calculated the mixed layer depth (see Fig.2-f) based on the difference criteria, ~~of with~~in which sigma theta changed by 0.03 kg/m^3. The MLD values at the stations along the cruise were later gridded linearly to match the spatial ~~and temporal~~ resolution of the underway measurements. ~~in situ data along the cruise track.~~


Sea surface pCO$_2$(μatm)
Atmospheric pCO$_2$(μatm)
Sea surface salinity (psu)
Sea surface temperature (C)
Chlorophyll a concentration (mg/m^3)
Mixed Layer Depth (m)
65°E
70°E
75°E
80°E
64°S
65°S
66°S
67°S
68°S
69°S
70°S
400
350
300
250
200
150
390
387.5
385
382.5
380
377.5
375
33.5
33
32.5
32
31.5
1
0.5
0
-0.5
-1
-1.5
12
10
8
6
4
2
0
40
30
20
10
Ocean Data View
a
b
c
d
e
f

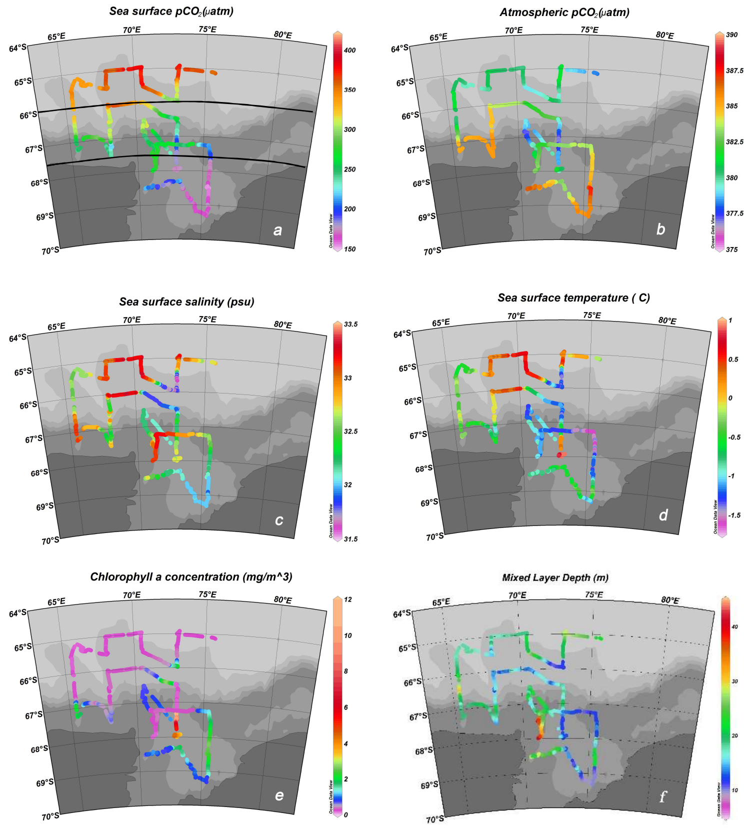


Fig.2 The distributions of underway oceanic and atmospheric pCO$_2$, SST, SSS, and CHL gridded from MODIS, as well as MLD gridded from station surveys, from February to early March.~~the distributions of underway oceanic and atmospheric pCO$_2$, SST, SSS, and CHL gridded from MODIS, and MLD gridded from stations surveys.~~

2.2 SOM method and input variables

We hypothesize that oceanic pCO$_2$ can be reconstructed ~~through~~ using the SOM ~~based multiple non-linear regression~~method with four proxy parameters (Eq. 1): sea surface temperature (SST), chlorophyll-a concentration (CHL),~~the abundance of photo-synthesizing organisms in the surface ocean represented by the chlorophyll-a concentration (CHL),~~ mixed layer depth (MLD), and sea surface salinity (SSS).

$$pCO_2^{sea}=\mathrm{SOM}\ (SST, CHL, MLD, SSS) \qquad (1)$$

The SOM is trained ~~using unsupervised learning to project~~to project the input space of training samples to a feature space (Kohonen, 1984), which is usually represented by grid points in two-dimension space. Each grid point, which is also called a neuron cell, is associated with a weight vector having the same number of components as the vector of input data (Zeng et al., 2017). During the SOM analysis, three steps are taken to estimate oceanic pCO$_2$ fields (see Fig. 3). ~~Input variables to estimate pCO$_2$ are prepared in a vector form.~~ The input environmental parameters(in this study, SST, CHL, MLD, and SSS)used to estimate pCO$_2$ are prepared as a vector. Here, ~~T~~the SOM analysis was carried out ~~by~~ using the MATLAB SOM tool box 2.0 (Vesanto, 2002). It has been developed by the Laboratory of Computer and Information Science in the Helsinki University of Technology and is available from the following web page: http://www.cis.hut.fi/projects/somtoolbox.

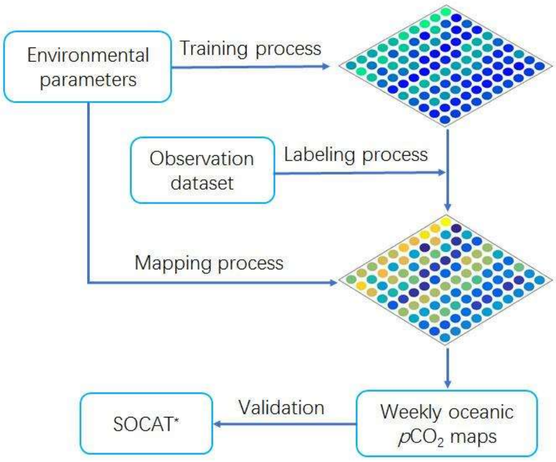


Fig. 3. Schematic diagram of the main three steps involved in the SOM neural network calculations used to obtain weekly pCO_2 maps for February to early March of 2015.~~Schematic scheme of the main three step involved in the SOM neural network calculations leading to weekly pCO_2 maps for February 2015.~~

During the training process, each neuron's weight vectors are repeatedly trained by being presented with the input environmental parameters in the SOM training function. Because SOM analysis is known to be a powerful technique with which to estimate pCO_2based on the non-linear relationships of the parameters (Telszewski et al., 2009), we assumed that the non-linear relationships of the proxy parameters are sufficiently represented after the training procedure. This process results in the clustering of similar neurons and the self-organization of the map. The observed oceanic pCO_2 data are not needed in the first step.

During the second part of the process, each preconditioned SOM neuron is labelled with an observation dataset of in situ oceanic pCO_2values. The labelling dataset, which consists of the observed pCO_2 and normalized SST, CHL, MLD and SSS data, is presented to the neural network. We used Euclidean distances (i.e., the shortest distances) to select the winner neurons. After the labelling process, the neurons are represented as five-dimensional vectors.

Finally, during the mapping process, the labelled SOM neurons created by the second process and the trained SOM neurons created by the first process are used to produce the oceanic pCO_2value of each winner neuron based on its geographical grid point in the study area.

Before the training process, the input training dataset and labelling dataset are analysed and prospectively normalized to create an even distribution. The statistics and ranges of the values of all variables are presented in Table 1. When the datasets of the four proxy parameters were logarithmically normalized, the skewness values of CHL and MLD changed, especially for the training dataset. The *N* coverage represents the percentage of the training data that are labelled. The data *N* coverage values of the training data sets of CHL, MLD and SSS are 82.1%, 85% and 81.1%, respectively, which maybe due to their insufficient spatiotemporal coverage and/or bias between the labelling and training data sets. The *N* coverage of the logarithmic datasets changed to 93.6% and to 98.7%for CHL and MLD, respectively. Thus, the common logarithms of the CHL and MLD values are used for both the training and labelling datasets to resolve the data coverage issue arising from significantly increasing the data coverage as well as to overcome the weighting issue arising from the different magnitudes between variables (Ultsch and Röske, 2002).

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带格式的: 英语(英国)

~~More realistic $p\mathrm{CO}_2$ estimates were expected from the SOM analysis when the distribution and variation range of the labeling variables closely reflect the training data sets (Nakaoka et al., 2013) while our underway measurements with $p\mathrm{CO}_2$ value have a spatiotemporal limitation to cover the range of the variation of training data sets. Before the training process, the input training dataset and labeling dataset are analyzed and prospectively normalized to make an even distribution. The statistics and range of the values of each variable are presented in Table1. When the dataset of four proxy parameters were logarithmically normalized the skewness of CHL and MLD changed obviously especially for the training dataset. The *N* coverage represents the percentage of the training data that are labeled. The data *N* coverage of training data set of CHL, MLD and SSS are 82.1%, 85% and 81.1% respectively, which might be due to the insufficient spatiotemporal coverage and or bias between the labeling and training data sets. The *N* coverage of the logarithmically datasets changed to 93.6% and to 98.7% respectively for CHL and MLD. Thus the common logarithm of CHL and MLD values are used for both the training and labeling datasets in order to resolve the data coverage issue from significantly increasing the data coverage as well as to overcome the weighting issue raised from the different magnitude among the variables (Ultsch and Röske, 2002).~~

Table 1. Statistics of labeling and training data sets showing the distribution and coverage of each variable.

Coverage of each variable		SST(C)	CHL(mg/m^3)	MLD(m)	SSS(psu)
Labeling	Max	0.81	11.13	40.69	33.81
	Min	-1.44	0.17	7.84	32.43
	Mean	-0.27	3.80	14.41	33.27
	Skewness	0.4(-0.2)[#]	0.8(-0.3)	0.9(0.4)	0.6(0.6）
Training	Max	2.48	40.17	48.95	34.17
	Min	-1.8	0.06	10.46	28.64
	Mean	-0.53	1.36	14.79	33.16
	Skewness	0.5(-0.6)	4.3(0.5)	2.6(0.8)	-0.9(-1.0)
	N coverage* (%)	91.3(92.5)[+]	82.1(93.6)	85.0(98.7)	81.1(80.4)

the skewness of common logarithm of each variable is shown in the parenthesis.

* [number of training data within the labeling data range]/[total number of training data]

+ the percent labeling data coverage of normalized variables is shown in the parenthesis

~~During the training process, a neuron's weight vectors are repeatedly trained by being presented with the input vectors, until the neural network sufficiently represents the nonlinear interdependence of proxy parameters used in training. This process results in clustering of similar neurons and self-organization of the map. The observed oceanic $p\mathrm{CO}_2$ is not needed at the first step.~~

~~During the second process, each preconditioned SOM neurons is labeled with an observed oceanic $p\mathrm{CO}_2$ value. The labeling dataset consisting of the observed $p\mathrm{CO}_2$ and the normalized SST, CHL, MLD and SSS is presented to the neural network and then a winner neuron is found. After the labeling process, neurons are represented by five-dimensional vectors.~~

~~Finally, during the mapping process, the labeled SOM neurons created by the second process and trained SOM neurons created by the first process are used to produce oceanic $p\mathrm{CO}_2$ of the winner neuron according to the geographical grid points of the study area.~~

In this study, we construct weekly oceanic $p\mathrm{CO}_2$ maps from February to early March of 2015 using four datasets, i.e., SST, CHL, MLD, and SSS.~~We used four datasets including SST, CHL, MLD, and SSS **(SCMS)** to train the SOM.~~ Considering the size of our study region, we chose a spatial resolution of 0.1° latitude by 0.1° longitude. For SST, we used daily data from AVHRR ONLY (https://www.ncdc.noaa.gov/oisst) with a ~~of~~ 1/4° spatial resolution (see Fig.S1). CHL data represent ~~are~~ the 8-D composite chlorophyll-a data from MODIS-Aqua (http://oceancolor.gsfc.nasa.gov) ~~at~~ with a space resolution of 4km (see Fig.S2). We also used the daily SSS and MLD data (see Fig.S3-4) from the 1/12° global analysis and forecast product from the Copernicus Marine Environment Monitoring Service (CMEMS, http://marine.copernicus.eu/). Sea ice concentration data are~~is~~ from the daily 3.125-km AMSR2 dataset (Spreen et al., 2008, available on https://seaice.uni-bremen.de, see Fig.S5).

All ~~the~~ daily datasets were first averaged to ~~be~~ 8-d fields, which are regarded as weekly ~~for~~in this study. The period from the beginning of February to early March comprises~~From the beginning of February to the early of March we have~~ four independent week series, which are week-1 (from 02/02/2015 to 02/09/2015), week-2 (from 02/10/2015 to 02/17/2015), week-3 (from 02/18/2015 to 02/25/2015), and week-4 (from 02/26/2015 to 03/05/2015). The weekly proxy parameters (**SCMS**) were further re-gridded ~~with~~ to a horizontal resolution of 0.1° · 0.1° using the Kriging method. In the SOM analyses, input vectors with missing elements are excluded. ~~Consequently, oceanic $p\text{CO}_2$ created in this study has weekly frequency and 0.1 longitude · 0.1 latitude resolution from 63°E to 83°E and 64°S to 70°S.~~

We compared the assimilated datasets of SST from AVHRR with the in situ measurements obtained by CTD along the cruise. Their relationship is 0.97, and their root-mean-square error (RMSE) is 0.2°C. Comparing t~~T~~he SSS and MLD fields from the Global Forecast system ~~compare reasonably well~~ with the in situ measurements~~, with relationships~~yields correlations of 0.76 and 0.74, ~~respectively~~ and ~~the~~ RMSEs of 0.41 and 5.15m, respectively. The uncertainty of the MODIS~~odis~~ CHL data in the Southern Ocean is approximately~~about~~ 35% (Xu et al., 2016). For the labelling procedure, the observed oceanic $p\text{CO}_2$ together with the corresponding in situ SST, SSS, MLD, and ~~Modis~~ MODIS CHL products in vector form are used as the input dataset.

2.3 Validation of ~~SOM derived~~SOM-derived oceanic $p\text{CO}_2$

More realistic $p\text{CO}_2$ estimates are expected from SOM analyses when the distribution and variation ranges of the labelling variables closely reflect those of the training data sets (Nakaoka et al., 2013). However, our underway measurements of$p\text{CO}_2$values have spatiotemporal limitations preventing them from covering the range of variation of the training data sets. To validate the oceanic $p\text{CO}_2$values reconstructed by the SOM analysis, we used the fugacity of oceanic CO_2 datasets from the Surface Ocean CO_2 Atlas (hereafter referred to as “SOCAT” data,http://www.socat.info) version 5 database (Bakker et al., 2016).We selected the dataset from SOCAT(the EXPOCODE is 09AR20150128, see cruise in Fig. 4a) that coincided with the same period as our study. The cruise lasted from Feb. 6 to Feb. 27, 2015, and $f\text{CO}_2$ measurements were made every 1 min at a resolution of 0.01°. We recalculated $p\text{CO}_2$ values based onthe obtained $f\text{CO}_2$values provided by the SOCAT data using the fugacity correction (Pfeil et al., 2013).~~To validate the oceanic $p\text{CO}_2$ reconstructed by the SOM analysis, we used the fugacity of oceanic CO_2 datasets (referred as “SOCAT” data hereinafter) from the Surface Ocean CO_2 Atlas (SOCAT: http://www.socat.info) version 5 database (Bakker et al., 2016). In Pacific Ocean, the Atlantic Ocean or regions away from coast, datasets from different years can be assimilated to a reference year to have a good spatial coverage according to the equilibrium between sea surface and atmosphere (Takahashi et al., 2006; Wong et al., 2010; Nakaoka et al., 2013). However, the same approach should be applied carefully because the sea ice condition varies from year to year in the Southern Ocean. The sea ice cover has a great impact on the oceanic $p\text{CO}_2$. SOCAT data in February from different years do have a good spatial coverage in Prydz Bay. However we~~

~~could only select dataset for our study period in 2015 (see Fig. 4-a) although it covers limited area in study region. We recalculated pCO_2 values from the obtained fCO_2 offered in SOCAT data according to the fugacity correction (Pfeil et al., 2013).~~

2.4 Carbon uptake in the Prydz Bay

The flux of CO_2 between the atmosphere and the ocean was determined using ΔpCO_2 and the transfer velocity across the sea-air interface, as shown in Eq. 2, where K is the gas transfer velocity (in cm h^{-1}), and the quadratic relationship betweenwind speed (in units of m s^{-1}) and the Schmidt number is expressed as $(Sc/660)^{-0.5}$.~~by two items.~~ L is the solubility of CO_2 in seawater (in mol $litre^{-1}$ atm^{-1}) (Weiss, 1974). For the weekly estimation in this study, the scaling factor for the gas transfer rate is changed to 0.251 for shorter time scales and intermediate wind speed ranges (Wanninkhof, 2014). Considering the unit conversion factor (Takahashi et al., 2009), the weekly sea-air carbon flux in the Prydz Bay can be estimated using Eq. (3): ~~One is the difference in CO_2 concentration across the sea-air interface and the other is the transfer velocity which is a function primarily of wind speed and temperature. The equation to calculate the sea-air carbon flux was simplified as a function of wind speed and delta pCO_2 (from sea to air) in eq. 2, Xu et al. (2016). For the weekly estimation in this study, the scaling factor for the gas transfer rate is changed to 0.251 for a shorter time scale and at intermediate wind speed ranges (Wanninkhof, 2014). For each grid, weekly sea-air carbon flux in the Prydz Bay can be estimated by Eq. (2):~~

$$Flux_{sea\text{-}air} = K \times L \times \Delta pCO_2 \qquad (2)$$

$$Flux_{sea\text{-}air}[g\ C/(m^2 \cdot week)] = 30.8 \times 10^{-4} \times U^2 \times (pCO_2^{sea} - pCO_2^{air}) \qquad (3)$$

where U represents the wind speed 10 m above sea level, and pCO_2^{sea} and pCO_2^{air} are the partial pressures of CO_2 in sea water and the atmosphere, respectively.

~~$Flux_{sea\text{-}air}(g\ C/(m^2 \cdot week)) = 30.8 \times 10^{-4} \times U^2 \times (pCO_2^{sea} - pCO_2^{air}) \qquad (2)$~~

~~where U represents wind speed 10 m above sea level, pCO_2 sea and pCO_2 air are partial pressure of CO_2 in sea water and atmosphere.~~

We downloaded weekly ASCAT wind speed data (http://www.remss.com/, see Fig. S6) with a ~~of~~ 1/4° ~~degree~~ and then ~~re~~gridded the dataset to fit the 0.1° longitude · 0.1° latitude spatial resolution of the SOM-derived oceanic pCO_2. We ~~re~~gridded the atmospheric pCO_2 collected along the cruise track to fit the spatial resolution of the SOM-derived oceanic pCO_2 data using a ~~by~~ linear method. The total carbon uptake was then obtained by accumulating the flux of each grid ~~by~~ in each area according to Jiang et al. (2008) and using the proportion of ice-free areas

(Takahashi et al., 2012). When the ice concentration is less than 10% in a grid, we regard the grid box ascomprising all water. When the ice concentration fallsbetween 10% and 90%, the flux is computed as being proportional to the water area. In the cases of leads or polynyas due to the dynamic motion of sea ice (Worby et al., 2008), we assume the grid box to be 10% open water when the satellite sea ice cover is greater than90%.~~with the proportion of ice-free area (Xu et al., 2016).~~

3 Results and discussion

3.1 the distributions of underway measurements

During austral summer, daylight lasts longer and solar radiation increases. With increasing sea surface temperature, ice shelves break and sea ice melts, resulting in the stratification of the water column.~~From~~ Starting in the beginning of February, R/V Xuelong sailed from east to west along the sea ice edge, and its underway measurements are shown in Fig.2. Based on the water depth and especially the different ranges of oceanic pCO$_2$ (see Fig.2a and Table2),~~Based on the water depth and the sea ice condition,~~ the study area can be roughly divided into three regions, namely, the Open-ocean region, Sea-ice region and Shelf region (see Table2).~~the study area is robustly divided into three regions, the Open-ocean region, Sea-ice region and the Shelf region.~~

The Open-ocean region ranges northward from 66°S to 64°S, where~~was from 66°S northward to 64°S~~ ~~where locates~~ the Antarctic Divergence Zone is located and ~~with~~ water depths are greater than 3000 m. In the Open-ocean region, the oceanic pCO$_2$was the highest, varying from 291.98 µatm to 379.31 µatm, with a regional mean value of 341.48 µatm. The Antarctic Divergence Zone~~AD zone~~ was characterized by high nutrients and low chlorophyll ~~(HNLC)~~ concentrations, with high pCO$_2$ attributed to the upwelling of deep waters, thus suggesting the importance of physical processes in this area (Burkill et al., 1995; Edwards et al., 2004). ~~U~~The underway sea surface temperature in this region are relatively high, with an average value of -0.23°C~~0.36°C~~ due to the upwelling Circumpolar Deep Water (CDW), while ~~in~~at the sea ice edge (73°E, 65.5°S to 72°E, 65.8°S), the SST decreased ~~below~~ to less than -1°C. From 67.5°E westward, affected by the large gyre, cold water from ~~the~~ high latitude lowered ~~down~~ the SST to ~~below~~ less than 0°C. Near the sea ice edge, SSS decreased quickly to 31.7 psu due to the diluted water~~,~~ ; ~~while~~ along the 65°S cruise, it reached to 33.3 psu~~,~~; ~~and~~ then, moving westward~~ern~~ from 67.5°E, affected by the fresher and colder water brought by the large gyre, it decreased to 32.5

psu. The satellite chlorophyll-a image showed that the regional mean was as low as~~it was of low value of~~ 0.45 mg/m^3, except when the vessel near the sea ice edge recorded CHL values that increased to be 2.26 mg/m^3. The lowest pCO$_2$value was found near the sea ice edge due to biological uptake. The distribution of MLD varied along the cruise. Near the sea ice edge, because of the melting of ice and direct solar warming, ~~it constituted~~ a low-density cap existed over the water column, and the MLD was as shallow as 10.21 m. The maximum value of MLD in the Open-ocean region was~~is~~ 31.67 m. In the Open-ocean region, atmospheric pCO$_2$ ~~was~~varied ~~stable~~ from 374.6 µatm to 387.8 µatm. ~~Oceanic pCO$_2$ varied from 291.98 µatm to 379.31 µatm with an average value of 341.48 µatm.~~ Along the 65°E cruise in the east part of the Open-ocean region, the oceanic pCO$_2$ was relatively high, reaching ~~an~~ equilibrium with atmospheric pCO$_2$. ~~The lowest value was found near the sea ice edge due to biological consume. For~~ In the western part of this region, the oceanic pCO$_2$ decreased ~~a little~~slightly due to the mixture of low pCO$_2$ from higher latitudes brought by the large gyre. Mixing and upwelling were the dominant factors ~~for~~ affecting the oceanic pCO$_2$ in this region.

The seasonal Sea-ice region (from 66°S to 67.25°S) is located between the Open-ocean region and the Shelf region. In this sector, sea ice changed strongly, and the water depth varied sharply from 700 m to 2000 m. The oceanic pCO$_2$values ranged from 190.46 µatm to 364.43 µatm, with a regional mean value of 276.48 µatm. Sea ice continued to change and reform from late February to the beginning of March (Fig. 6).~~Sea ice kept changing and reforming from the late of February to the beginning of March.~~ The regional mean sea~~Sea~~ surface temperature decreased slightly compared to that in the Open-ocean region, and the average value was -0.72°C. With the rapid changes in sea ice~~ changing~~, the sea surface temperature and salinity varied sharply from -1.3°C to 0.5°C and from 31.8 psu to 33.3 psu, respectively. When sea ice melted, the water temperature increased, biological activity increased, ~~activities became active~~ and chlorophyll-a value increased slightly to reach a regional~~by a small amount to an~~ average of 0.5~~1~~9 mg/m^3. Due to the rapid change in~~of~~ sea ice cover, the value of MLD varied from 12.8 m to 30.9 m. ~~The average value of oceanic pCO$_2$ was 276.48 µatm ranging from 190.46 µatm to 364.43 µatm.~~

The Shelf region (from 67.25°S southward) is characterized by shallow depths of less than~~of low depth below~~ 700m, and it is surrounded~~surrounding~~ by the Amery Ice Shelf~~,~~ and the West Ice Shelf. Water inside the Shelf region is formed by the ~~, and the stretching permanent sea ice~~

~~from the West Ice Shelf, formed by~~ modification of ~~low~~ low-temperature and high-salinity shelf water (Smith et al., 1984). ~~Two shallow banks (<200m): Fram Bank to the north-west and Four Ladies Bank to the north-east, forming a spatial barrier for the inner shelf to water exchange with the outer oceanic water (Smith and Tréguer, 1994).~~ The Prydz Bay coastal current flows~~ed~~ from east to west in the semi-close bay. The oceanic pCO$_2$values in this region were the lowest of those in all three sectors; these values ranged from 151.70 µatm to 277.78 µatm,with a regional average of 198.72 µatm.~~There is always a~~A fresher, warmer surface layer is always present over the bay, which is known as the Antarctic Surface Water (ASW). During our study period, the Shelf region was the least ice-covered region~~completely ice free,~~. ~~a~~A large volume of freshwater was released into the bay, resulting in low sea surface temperature (an average of -0.61°C) and salinity (an average is 32.4 psu). As shown in Fig.2-f, the mixed layer depth in most of the inner shelf is low~~ in most of the inner shelf~~. Due to the vast shrink of sea ice and strong stratification in the upper water, algal blooming occurred~~ed~~ and chlorophyll values were~~as~~ high, with an average of 1.93 mg/m^3. The oceanic pCO$_2$ in this region turned out to be the lowest in three sectors. ~~The average of oceanic pCO$_2$ is 198.72 µatm with a range from 151.70 µatm to 277.78 µatm.~~ The chlorophyll-a value was remarkably high, reaching11.04 mg/m^{3}when sea ice retreated eastwardly from 72.3°E, 67.3°S to 72.7°E, 68°S.~~Chlorophyll-a value shows remarkably as high as 11.04 mg/m^3 from 72.3°E, 67.3°S to 72.7°E, 68°S when sea ice retreated eastwardly.~~ The biological pump became the dominant factor controlling the distribution of oceanic pCO$_2$. In the bay mouth close to the Fram Bank, due to local upwelling, the water salinity increased remarkably toapproximately33.2 psu.~~In the bay mouth close to the Fram Bank, due to the local upwelling water salinity increased remarkably to around 33.2. Biological pump becomes the dominant factor of the distribution of oceanic pCO$_2$.~~

Table 2 The regional mean values of underway measurements in three sub-regions

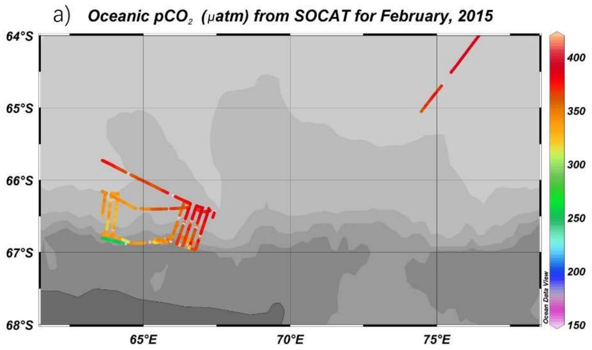
	pCO$_2$ [µatm]	SST [°]	CHL [mg/m^3]	MLD [m]	SSS [psu]
Open-ocean region (66°S - 64°S)	341.48	-0.23	0.45	20.13	32.61
Sea-ice region (66°S - 67.25°S)	276.48	-0.72	0.59	19.44	32.42
Shelf region (67.25°S - 70°S)	198.72	-0.61	1.95	16.84	32.46

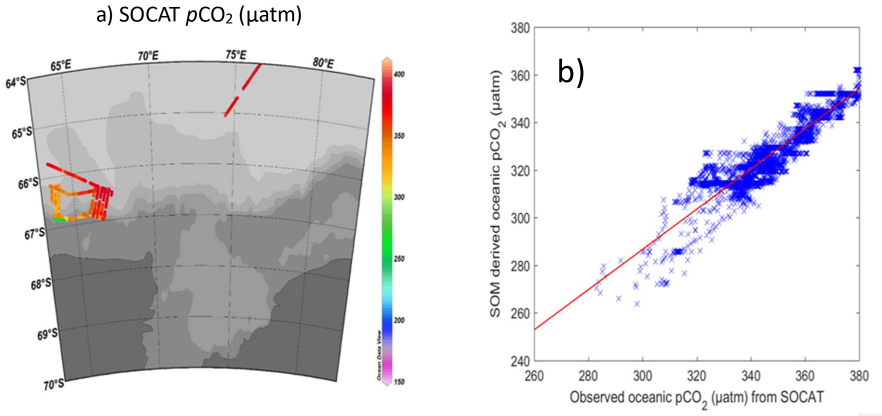
3.2 Quality and maps of ~~SOM derived~~SOM-derived oceanic $p\mathrm{CO}_2$

We selected ~~SOM derived~~SOM-derived oceanic $p\mathrm{CO}_2$ values to fit the cruise track of SOCAT for ~~a~~the same period in February 2015 using a nearest grid method. ~~The slope of the scatter plot showed that SOM derived oceanic $p\mathrm{CO}_2$ is lower than the SOCAT data (see Fig. 4 b).~~ The RMSE between the SOCAT data and the~~SOM derived~~SOM-derived result wa~~i~~s calculated as follows:

$$RMSE = \sqrt{\frac{\Sigma\left(pCO_2^{sea}(SOM) - pCO_2^{sea}(SOCAT)\right)^2}{n}} \qquad (4\cancel{3})$$

where n is the number of the validation datasets. The RMSE can~~ould~~ be ~~used~~ interpreted as an estimation of the uncertainty in the~~SOM derived~~SOM-derived oceanic $p\mathrm{CO}_2$ in the Prydz Bay. In this study, the RMSE of the SOM-derived oceanic $p\mathrm{CO}_2$ and SOCAT datasets is 22.14 µatm, and the correlation coefficient R^2 is 0.82. The absolute mean difference is 23.58 µatm. The RMSE obtained in our study~~This~~ is consistent with the accuracies~~y~~ (6.9 µatm to 24.9 µatm) obtained ~~achieved~~ in previous studies that used neuron methods to reconstruct oceanic $p\mathrm{CO}_2$~~using neuron methods to reconstruct oceanic $p\mathrm{CO}_2$~~ (Nakaoka et al., 2013, Zeng et al., 2002; Sarma et al., 2006; Jo Y H et al., 2012; Hales et al., 2012; Telszewshi M., et al., 2009). ~~However, this~~The precision of this study is on the high side of those that have been previously reported~~not as good as most of the neuron methods~~. The slope of the scatter plot indicates that the SOM-derived oceanic $p\mathrm{CO}_2$data are lower than the SOCAT data (see Fig. 4b). Thus, the precision of these data may have greater uncertainty because the SOCAT dataset does not cover the low-$p\mathrm{CO}_2$ area towards the south. Thus, ~~I~~increasing the spatial coverage of the labelling data will help to increase the precision of ~~SOM derived~~ the SOM-derived oceanic $p\mathrm{CO}_2$.


a)
Oceanic pCO₂ (μatm) from SOCAT for February, 2015
64°S
65°S
66°S
67°S
68°S
65°E
70°E
75°E
400
350
300
250
200
150
Ocean Data View


a) SOCAT pCO₂ (μatm)
65°E
70°E
75°E
80°E
64°S
65°S
66°S
67°S
68°S
69°S
70°S
400
350
300
250
200
150
Ocean Data View
b)
SOM derived oceanic pCO₂ (μatm)
Observed oceanic pCO₂ (μatm) from SOCAT
240
260
280
300
320
340
360
380

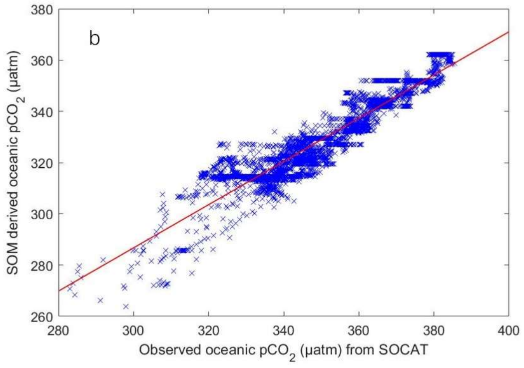

b
SOM derived oceanic pCO₂ (μatm)
Observed oceanic pCO₂ (μatm) from SOCAT
260
280
300
320
340
360
380
400

Fig. 4 a)The cruise lines from SOCAT used to validate the SOM-derived oceanic pCO_2 for the study period in 2015; b) comparison between the SOM-derived and observed SOCAT oceanic pCO_2data ~~a)The cruise lines from SOCAT to validate the SOM derived oceanic pCO_2 for the study period in 2015; b) Comparison between the SOM derived and observed SOCAT oceanic pCO_2.~~

3.3 Spatial and temporal distributions of ~~SOM derived~~SOM-derived oceanic pCO_2

The weekly mean maps of SOM-derived oceanic pCO_2 in the Prydz Bay are shown in Fig. 5. In the Open-ocean region, the oceanic pCO_2 values were higher than those in the other two regions due to the upwelling of the CDW. During all four weeks, this region was nearly ice-free, while the average sea ice coverage was 18.14% due to the presence of permanent sea ice (see Fig.6). The oceanicpCO_2 distribution decreased from east to west in the Open-ocean region, with lower values observed at the edge of sea ice. In the western part of the Open-ocean region, oceanic pCO_2 decreased due to mixing with low oceanic pCO_2 flowing from high-latitude regions caused by the large gyre. From week-1 to week-4, the maximum oceanic pCO_2 increased slightly and reached 381.42 µatm, which was equivalent to the pCO_2 value of the atmosphere.

In the Sea-ice region, sea ice continued to rapidly melt and reform. The weekly mean sea ice coverage percentage was 29.54%, occupying nearly one-third of the Sea-ice region. As shown in Fig.5, the gradient of the oceanic pCO_2 distribution increased from south to north affected by the flow coming from the Shelf region by the large gyre. In the eastern part of this region, adjacent to the sea ice edge, the oceanicpCO_2 values were lower. The oceanic pCO_2 changed sharply from 155.86 µatm (near the sea ice edge) to 365.11 µatm (close to the Open-ocean region).

In austral winter, the entire Prydz Bay basin is fully covered by sea ice, except in a few areas, i.e., the polynyas, which remain open due to katabatic winds (Liu et al., 2017). When the austral summer starts, due to coincident high wind speeds, monthly peak tides, and/or the effect of penetrating ocean swells, the sea ice in the Shelf region starts to melt first in early summer (Lei et al., 2010), forming the Prydz Bay Polynya. The semi-closed polynya functions as a barrier for water exchange in the Shelf region and causes a lack of significant bottom water production, hindering the outflow of continental shelf water and the inflow of Antarctic circle deep water, resulting in the longer residence time of vast melting water and enhanced stratification (Sun et al., 2013).Due to vast melting of the sea ice, the sea surface salinity decreased and algae bloomed; biological productivity promptly increased, and the chlorophyll-a concentration reached itspeak value. As shown in Fig. 5, the distribution of oceanic $p\mathrm{CO}_2$ in the Shelf region was characterized by its lowest values. The obvious drawdown of oceanic $p\mathrm{CO}_2$occurred in the Shelf region due to phytoplankton photosynthesis during this summer bloom. The lowest oceanic $p\mathrm{CO}_2$ in the Shelf region was 153.83 µatm, except at the edge of the West Ice Shelf, where the Shelf oceanic $p\mathrm{CO}_2$exceeded 300 µatm. The oceanic $p\mathrm{CO}_2$ was the lowest in week-1, which coincided with a peak in chlorophyll-a, as evidenced by satellite images. The regional oceanic $p\mathrm{CO}_2$ increased slightly in week-4 compared to the other three weeks.

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~~In austral winter, the entire Prydz Bay basin is fully covered by sea ice except for a few areas, the polynyas, remaining open due to katabatic winds (Liu et al., 2017). As the austral summer starts, with the increasing sunlight, sea surface temperature increased, ice shelf broke and drifted out. Due to coincident high wind speeds, monthly peak tides, and/or the effect of penetrating ocean swell, sea ice in the Shelf region started to melt in early summer (Lei et al., 2010), forming Prydz Bay Polynya. The AMSR2 sea ice extent and mean ice concentration in each region are shown in Fig. 5, respectively. The Shelf region has the least sea ice extent (1.38x10^{4}km^2) and concentration (13.54%), without significant temporal variation. The semi-close polynya functions as a barrier for water exchange in the Shelf region and lack of significant bottom-water production, hindering outflow of continental shelf water and inflow of Antarctica circle deep water, resulting in a longer residence time for the vast melting water and enhanced stratification (Sun et al., 2013). Due to vast sea ice melting, sea surface salinity decreased, algae bloomed, the biological productivity increase promptly, the value of chlorophyll-a concentration reached the peak, the Shelf region became a strong CO_2 sink. As shown in Fig. 6, an obvious drawdown of oceanic $p\mathrm{CO}_2$ in Shelf region due to phytoplankton photosynthesis during the summer bloom. The lowest oceanic $p\mathrm{CO}_2$ in the Shelf region was 153.83 µatm except in the edge of West Ice Shelf oceanic $p\mathrm{CO}_2$ reached over 300 µatm. The oceanic $p\mathrm{CO}_2$ was the lowest in week-1 (from 02/02/2015 to 02/09/2015) which is coincident with a peak/bloom in the~~

~~chlorophyll-a evidenced by the satellite images.~~

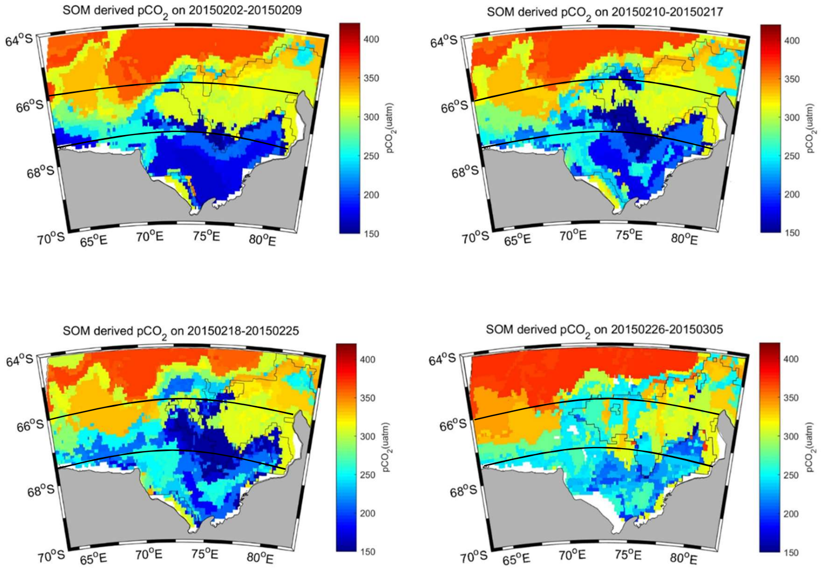


Fig.5 Distribution of weekly mean SOM-derived oceanic $p\mathrm{CO_2}$ in the Prydz Bay (unit: μatm) from Feb. 2, 2015 to Mar. 5, 2015. The black contour represents a sea ice concentration of 15%.

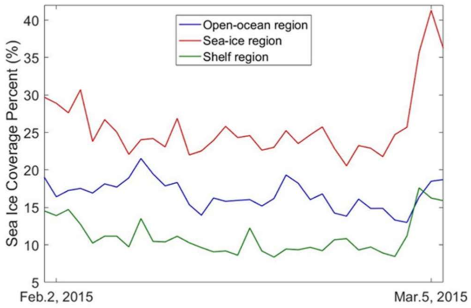
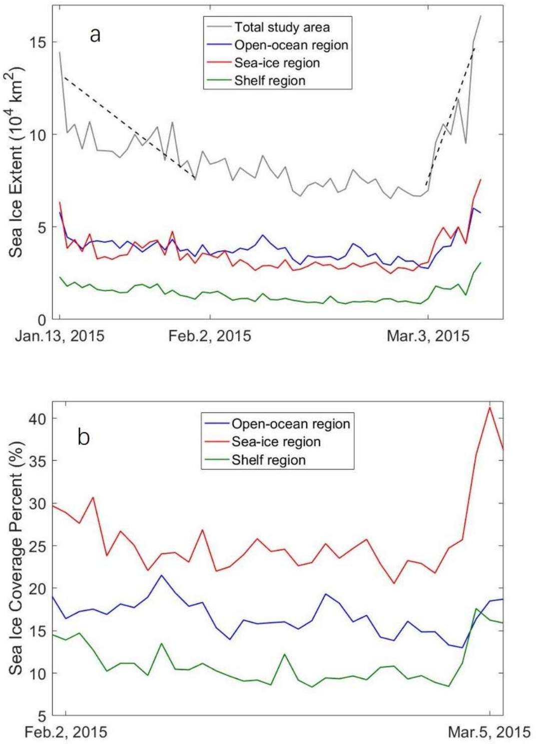


Fig. 6 Percentage ofsea ice coverage in three sub-regions from Feb. 2, 2015 to Mar. 5, 2015 (blue: Open-ocean region; red: Sea-ice region; green: Shelf region).



~~Fig. 5 a) Sea ice extent (unit: 10^4 km^2) in study area (gray line) and three sub-regions (blue: Open-ocean region; red: Sea-ice region; green: Shelf region); b) Averaged ice concentration in three sub regions from Feb. 2, 2015 to Mar. 5, 2015.~~

~~As shown in Fig.5-a, Sea ice in Open-ocean region and Sea-ice region started to melt from Jan 13, 2015, during February it decreased to the lowest and then it began to reform from Mar.3, 2015. The average sea ice extent in Open-ocean region and Sea-ice region were $3.85 \cdot 10^4$ km^2 and $3.56 \cdot 10^4$ km^2. During our study period, in the Sea-ice region, sea ice kept melting and reforming rapidly and the average value of sea ice coverage percent is 29.54%. Oceanic pCO$_2$ changed sharply from 155.86 μatm to 365.11 μatm.~~

~~In the Open-ocean region, sea ice started to melt in the beginning of February. In most area of the Open-ocean region it was sea ice free while the average sea ice coverage is only 18.14%.~~

~~The ice cover is mainly associated with the outstretching permanent sea ice. Affected by the upwelling CDW, the stability of water was weak and not suitable for the growth of phytoplankton. It is also evidence by, the observed biological productivity, which was below 0.5 mg/m^3. From the distribution of SOM derived oceanic pCO_2 as shown in Fig. 6, oceanic pCO_2 value was the highest compared to the Sea-ice region and the Shelf region. From week-1 to week-4, oceanic pCO_2 increased a little and reached 381.42 µatm which was equivalent to that of atmosphere. In the western part of Open-ocean region, oceanic pCO_2 decreased due to mixing with low oceanic pCO_2 flew from the high latitude by the large gyre.~~

Fig. 6 Weekly ~~SOM derived~~SOM-derived Prydz Bay pCO_2 (unit: µatm) distribution in February 2015, the black contour representing sea ice concentration of 15%.

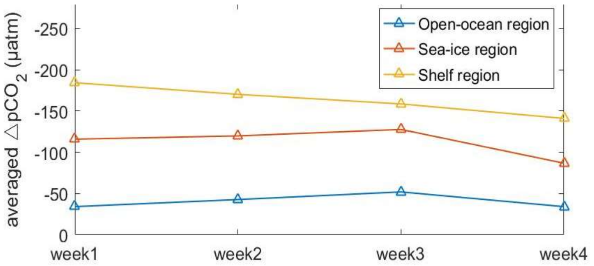
3.4 Carbon uptake in the Prydz Bay

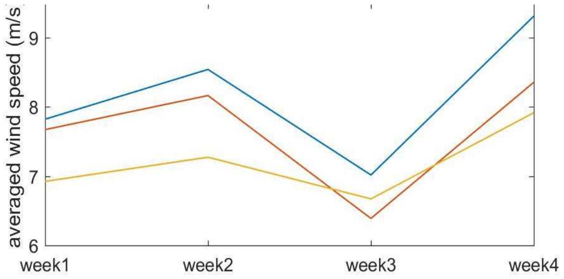
During our~~Over the whole~~ study period, the entire region was undersaturated, with CO_2 being absorbed by the ocean. The regional~~the~~ averaged ocean-air pCO_2 difference ($\triangle pCO_2$) wa~~i~~s high~~larg~~est in the Shelf region, ~~then follows~~followed by the Sea-ice region and Open-ocean region (see Table3). The regional and weekly mean $\triangle pCO_2$ ~~from~~ in the Shelf region changed from -184.31µatm in week-1 to -141.00 µatm in week-2~~to -141.00 µatm~~ as ~~the~~ chlorophyll decreased. The ΔpCO_2~~The sea-air difference of pCO_2~~ in the Sea-ice region and Open-ocean region showed the same patterns~~.~~, ~~It~~ increasing~~ed~~ from week-1 to week-3 then decreasing~~ed~~ in week-4. Based on the $\triangle pCO_2$ and wind speed data, the uptake of CO_2 in these three regions is presented in Table3.~~(eq. 2) in three regions is presented in Fig. 7~~. The uncertainty of the carbon uptake depends on the errors associated with the wind speed, the scaling factor and the accuracy of the SOM-derived pCO_2 according to Eq.3. The scaling factor will yield a 20% uncertainty in the regional flux estimation. The errors in the wind speeds of the ASCAT dataset ar eassumed to be 6% (Xu et al., 2016); the error in the quadratic wind speed is 12%.The RMSE ofthe SOM-derived $pCO_2$is 22.14 µatm. Considering the errors described above and the uncertainty occurring when the sea-air computation expression is simplified (1.39%, Xu et al., 2016), the total uncertainty of the final uptake is 27%. In the Shelf region, the low oceanic pCO_2 levels drove relatively intensive CO_2 uptake from the atmosphere. The ~~C~~carbon uptake in the Shelf region changed mildly from week-1 (2.51±0.68 TgC, 10^{12} gram=Tg) to week-2 (2.77±0.75 TgC).~~increased from week-1 (2.13 TgC) to week-2 (2.24 TgC) due to increased wind~~

~~speed~~. In contrast, in week-3~~While in week-3~~, wind speed slowed down, resulting in the uptake of CO_2 in Shelf region decreasing~~ed~~ to 2.10±0.57 TgC~~1.70~~ TgC. In week-4, even though the $\triangle pCO_2$ was the lowest of all four weeks, the total absorption still increased to be 2.63±0.715~~2.03~~ TgC due to the high wind speed (averaged value of 7.9 m/s). The total carbon uptake in the three regions of the Prydz Bay, integrated from February to early March of2015, was 23.57 TgC, with an uncertainty of ±6.36 TgC.

Table3 Regional and weekly mean ΔpCO_2, wind speed and uptake of CO_2in three sub-regions (negative values represent directions moving from air to sea).

		Week-1	Week-2	Week-3	Week-4	Uptake in 4 weeks[Tg]
Open-ocean region (66°S - 64°S)	ΔpCO_2 [µatm]	-34.11	-42.69	-51.94	-34.08	-5.74
	Wind speed [m/s]	7.82	8.54	7.02	9.31	
	Uptake [Tg]	-1.08	-1.55	-1.51	-1.60	
Sea-ice region (66°S - 67.25°S)	ΔpCO_2[µatm]	-115.92	-119.83	-127.74	-86.72	-7.82
	Wind speed[m/s]	7.67	8.17	6.39	8.36	
	Uptake [Tg]	-2.11	-2.35	-1.73	-1.63	
Shelf region (67.25°S - 70°S)	ΔpCO_2[µatm]	-184.32	-170.23	-158.61	-141.03	-10.01
	Wind speed[m/s]	6.92	7.27	6.67	7.92	
	Uptake [Tg]	-2.51	-2.77	-2.10	-2.63	





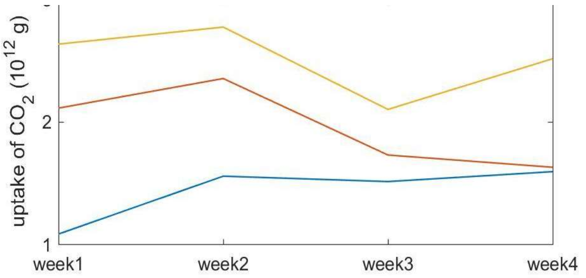


Fig. 7 Timeseries of weekly averaged $\triangle p\mathrm{CO_2}$, wind speed and uptake of atmospheric CO_2 in Open-ocean region (blue line, the negative value means the direction from sea to air), Sea-ice region (red line) and Shelf region (yellow line).

~~Studies have reported that Prydz Bay is a strong carbon sink in the austral summer.~~ Roden et al. (2013) estimated the coastal Prydz Bay to be an annual net sink for CO_2 of 0.54±0.11 mol/(m^2·year), i.e., 1.48±0.3 g/(m^2·week). Gibsonab et al. (1999) estimated the average~~d~~ sea-air flux in the summer ice-free period ~~sea-air flux~~ to be more than 30 mmol/(m^2·day), i.e., 9.2 g/(m^2·week). Our study suggests that the sea-air flux during the strongest period ~~in~~ of ~~a~~the year, i.e., February, could be much larger. The average flux obtained here, 18.84 g/(m^2·week), is twice ~~of the averaged~~ as large as the average value over a longer period (November to February) reported~~/estimated~~ by Gibsonab et al. (1999).

As the region recording the strongest surface unsaturation of these three regions in summer~~As the strongest surface unsaturation in summer~~, the Shelf region has a potential carbon uptake of 10.01±2.7 Tg C from February to early March, which accounts for approximately 5.0‰-6.7‰ ~~8.10 Tg C for February, which accounts for approximately 4.05‰-5.4‰~~ of the net global ocean CO_2 uptake according to Takahashi et al. (2009), even though its total area is only $78*10^3$ km^2~~while its total area is only $78*10^3$ km^2~~. Due to the sill constraint~~ of sill~~, there is limited exchange between water masses in and outside the Prydz Bay. During winter, the dense water formed by the ejection of brine~~ brine ejection~~ in the Bay~~,~~ can potentially uptake~~s~~ more anthropogenic CO_2 from the atmosphere~~, and~~ that can descend~~s~~ to greater depth, thus enhancing the acidification in~~ the~~ deep water. According to Shadwick et al. (2013), the winter values of pH and Ω decrease~~d~~ more remarkably than those in summer~~ values~~. As the bottom water in the

Prydz Bay is a possible source of Antarctic Bottom Water (Yabuki et al., 2006), the Shelf region may ~~act as to~~ transfer anthropogenic CO_2 at the surface to the deep water~~,~~ and ~~then~~ may thus influence the ~~deep ocean~~ acidification of the deep ocean over long timescales.~~in the long run~~.

~~The total carbon uptake in Prydz Bay of three regions integrated over the whole February 2015 was 18.7 TgC. The uncertainty depended on the errors for the wind speed, the scaling factor and the accuracy of SOM derived~~ ~~*p*CO_2 according to Eq.2. The scaling factor will yield a 20% uncertainty to regional flux estimation. The errors in wind speeds of Ascat dataset is assumed to be 6% (Xu et al., 2016) and will be 12% in quadratic wind speed. For the SOM derived~~ ~~*p*CO_2 the RMSE is 22.14 µatm. Considering the errors above and an uncertainty occurred when the sea-air computation expression was simplified (1.39%, Xu et al., 2016), the total uncertainty of the final uptake is ±4.93 TgC.~~

4 Summary

Based on the different observed ranges of the distribution of ocean *p*CO_2, ~~According to different controls factors of ocean~~ ~~*p*CO_2,~~ the Prydz Bay region was divided into three sectors from February to early March of 2015.~~for February 2015.~~ In the Shelf region, biological factors exerted~~was~~ the main control ~~for~~ on oceanic *p*CO_2, while in the Open-ocean region, mixing and upwelling ~~became~~ were the main controls. In the Sea-ice region, due to the rapid changes in sea ice~~ changing~~, oceanic *p*CO_2 was controlled by both~~ the~~ biological and physical processes. SOM is an important tool ~~to do~~for the quantitative assessment of oceanic *p*CO_2 and ~~succedent~~ its subsequent sea-air carbon flux, especially in dynamic, ~~high~~ high-latitude, and seasonally ice-covered regions. The estimated results revealed that the SOM technique could be used to reconstruct the variations ~~of~~ in oceanic *p*CO_2 associated with bio-geochemical processes expressed by the variability~~ies~~ in four proxy parameters: SST, CHL, MLD and SSS. The RMSE of the ~~SOM derived~~SOM-derived oceanic *p*CO_2 is 22.14 µatm for the SOCAT dataset. From February to early March of 2015,~~Over February 2015,~~ the Prydz Bay region was a strong carbon sink, with a carbon uptake of 23.57±6.36 TgC~~18.7±4.93 TgC~~. The ~~S~~strong potential uptake of anthropogenic CO_2 in the Shelf region will enhance the acidification in the deep water region of the Prydz bay and ~~then~~ may thus influence the acidification of the deep ocean ~~acidification~~ in the long run because~~since~~ it contributes to the formation of Antarctic ~~bottom~~ Bottom ~~water~~Water.

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Acknowledgments

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