nature portfolio

Peer Review File

Global warming may turn ice-free areas of Maritime and Peninsular Antarctica into potential soil organic carbon sinks

Corresponding Author: Dr Danilo Mello

This file contains all editorial decision letters in order by version, followed by all author rebuttals in order by version.

Attachments originally included by the reviewers as part of their assessment can be found at the end of this file.

Version 0:

Decision Letter:

** Please ensure you delete the link to your author home page in this e-mail if you wish to forward it to your coauthors **

Dear Mr Mello,

Your manuscript titled "Global warming drives Antarctica to become a soil organic carbon sink" has now been seen by 3 reviewers, whose comments are appended below. You will see that they find your work of some potential interest. However, they have raised quite substantial concerns that must be addressed. In light of these comments, we cannot accept the manuscript for publication, but would be interested in considering a revised version that fully addresses these serious concerns.

Specifically, for consideration of publication in Communications Earth and Environment, we require that you:
* rigorously demonstrate that warming (and not other environmental factors) is primarily driving changes in soil organic carbon in maritime Antarctica and the Antarctic Peninsula.
* transparently discuss uncertainties, caveats and limitations of the study, as pointed out by the reviewers.
* place your findings in the context of a balanced discussion of the most relevant literature.

We hope you will find the reviewers' comments useful as you decide how to proceed. Should additional work allow you to address these criticisms, we would be happy to look at a substantially revised manuscript. If you choose to take up this option, please either highlight all changes in the manuscript text file, or provide a list of the changes to the manuscript with your responses to the reviewers.

Please bear in mind that we will be reluctant to approach the reviewers again in the absence of substantial revisions.

If the revision process takes significantly longer than three months, we will be happy to reconsider your paper at a later date, as long as nothing similar has been accepted for publication at Communications Earth & Environment or published elsewhere in the meantime.

We are committed to providing a fair and constructive peer-review process. Please do not hesitate to contact us if you wish to discuss the revision in more detail.

Please use the following link to submit your revised manuscript, point-by-point response to the reviewers' comments with a list of your changes to the manuscript text (which should be in a separate document to any cover letter), a tracked-changes version of the manuscript (as a PDF file) and any completed checklist:

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Please do not hesitate to contact us if you have any questions or would like to discuss the required revisions further. Thank you for the opportunity to review your work.

Best regards,

Alice Drinkwater, PhD
Associate Editor
Communications Earth & Environment

EDITORIAL POLICIES AND FORMAT

If you decide to resubmit your paper, please ensure that your manuscript complies with our editorial policies and complete and upload the checklist below as a Related Manuscript file type with the revised article:

Editorial Policy Policy requirements
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For Manuscripts that fall into the following fields:
• Behavioural and social science
• Ecological, evolutionary & environmental sciences
• Life sciences
An updated and completed version of our Reporting Summary must be uploaded with the revised manuscript
You can download the form here:
https://www.nature.com/documents/nr-reporting-summary.zip

For your information, you can find some guidance regarding format requirements summarized on the following checklist: (https://www.nature.com/documents/commsj-phys-style-formatting-checklist-article.pdf) and formatting guide (https://www.nature.com/documents/commsj-phys-style-formatting-guide-accept.pdf).

REVIEWER COMMENTS:

Reviewer #1 (Remarks to the Author):

The manuscrip titled “Global warming drives Antarctica to become a soil organic carbon sink” aims to assess the potential impacts of global warming on SOC under three Shared Socioeconomic Pathways, using an integrated methodology that combines soil field data, machine learning, and future climate change scenario projections for the Antarctic cryosphere. Focusing on the 0–30 cm soil layer, the research findings indicate that most climate extremes lead to an increase in SOC stock (from 359 ± 146 Mg to 686 ± 197 Mg), suggesting that ice-free regions in Antarctica might act as carbon sinks. The study also finds that the predicted SOC stocks are primarily influenced by temperature and precipitation, which are linked to net primary productivity. In summary, studying how climate change could affect SOC reserves in Antarctica.
The manuscript is well structured, the citations, although they could be improved, are adequate. Almost all the figures are of high quality. I consider this manuscript to be suitable for the journal. My general opinion is that it is a carefully crafted manuscript, it deals with a very important topic and it does so in a novel way. However, I consider that the authors should make some important changes and even introduce new topics. These new issues are very important to understand how Antarctic ecosystems and soils may evolve with climate changet and could limit the applicability of this study.
Main concerns
1: The Soil Organic Carbon (SOC) in Antarctica primarily originates from several limited sources due to the continent's extreme conditions. Here are the main contributions to organic carbon in Antarctic soils: 1-Microorganisms: Most of the organic carbon in Antarctic soils comes from microorganisms such as bacteria, algae, and fungi. These organisms are capable of surviving in extreme conditions and play a crucial role in the production and decomposition of organic matter. 2-Lichens and Mosses: Although limited in number, lichens and mosses significantly contribute to the soil organic carbon in Antarctica. These organisms decompose very slowly due to low temperatures, allowing carbon to accumulate in the soil. 3-Marine mamals and Bird Deposits: In some coastal areas, deposits of organic material can come from marine sources like seaweed washed a shore and bird droppings (guano), which are rich in organic carbon and nutrients. Vascular Plants: The two native vascular plant species, Deschampsia antarctica and Colobanthus quitensis, although limited in distribution, also contribute to SOC through the deposition of their plant residues, which are decomposed by microorganisms. And perphas wind-Deposited Organic Material: Organic material can be transported to Antarctica through air currents. This material includes spores, pollen, and small fragments of plants from other parts of the world.
2: The authors of this paper have overlooked that a significant portion of the current SOC primarily originates from the usage of ice-free areas by fauna (marine mammals and birds) during the summer. Although predictive models suggest future colonization by vegetation, the geographical isolation of Antarctica poses a significant barrier. Even with changes in temperature and precipitation, the introduction of plant species other than Deschampsia antarctica (Antarctic hairgrass) and Colobanthus quitensis (Antarctic pearl grass), both of which contribute to soil carbon, may not take place. If the authors don't see a way to include these variables in their models, they should at least take it into account in the discussion. Antarctica cannot be treated like other areas of the planet with less isolation.
3: There should be important consideration of this source of uncertainty as it is not known how the rise in temperature would affect the behaviour of fauna. It is quite possible that many of these species that use the coasts of ice-free islands in summer

have substantial changes in their behavior (see https://doi.org/10.3390/rs16071192). It has a lot of cartographic information about the areas with faunal pressure. Also, in QAntartica the authors can find maps about the áreas under hight wildlife presure.
4: Another problem is in the definition of ice-free areas. Deception Island is considered to be ice-free and that's not true at all. 2/3 of Deception Island is ice cap (see for example Mount Pond or Irizart). This makes the carbon concentration vastly underestimated and all calculations made for Deception Island are affected by this error. In addition, Deception Island is used very intensively by wildlife in summer. Authors should correct these errors in the new versión.
5: Although the figures are of high quality and all of them necessary. Figure 4 needs to be reworked, because what the authors explain in the footer is not apparent in the figure. Authors could transform graphical scales into maps. Precipitation; temperature and PPN. Also, at the bottom of the figure they say that you see a correlation between SOC and PPN but it is not entirely true, especially in James Ross and Seymur islands. These areas show high concentration of SOC.
Minor concerns
6: Figure 5 should also show the relationship between the BIO13 variable and the increase in SOC.
7: Authors should also order the bibliographic citations: lines 37 contains citation number 5 and on line 43 is citation 9; 6, 7 and 8 are missing. Check if appointments are missing or out of order.

Reviewer #2 (Remarks to the Author):

The authors use a modeling approach to evaluate the effect of global warming on SOC stocks in Antarctica under three different climate change scenarios. The major concern regarding this manuscript is the discrepancy between the title (whole "Antarctica") and the region they investigate (Maritime Antarctica and the Antarctic Peninsula, see Fig. 3). The approach to project from one small region to the whole continent is not eligible. The authors themselves address the "high spatial heterogeneity of the Antarctic environments" - so they should know that it is not appropriate to project results from one rather special part to the whole continent. In addition, the authors juggle with buzzwords, and especially the Introduction lacks in large parts clear content. Regarding references, it
is often not clear why the authors chose the respective ones. Moreover, they tend to excessive self-citations and neglect other authors' work. However, in some parts, references are lacking. The whole manuscript reads in large parts not like the outcomes of scientific work, but like a description of what has been done (not only in the Method part where it belongs), explanations often seem to aim not at a scientific audience. In addition, large parts are not precise enough. Parts of the manuscript are wordy and the Discussion contains a large part about Arctic soils that do not fit here, especially not to this extent. A major part of the Discussion are factors and variables that were/could not be taken into account in the model but have a pronounced effect on SOC. However, also a "Limitations and uncertainties" section exists. The manuscript is therefore not well structured and needs to be revised completely. This work is not fit to be published in Communications Earth & Environment. See my detailed comments below:

Abstract
l. 21 I suggest replacing "from global warming" with "driven by global warming" or something similar.
l. 21 Please be precise regarding the term "climate extremes" - are you investigating the effect of warming or extreme events?
l. 26 "for the Antarctic cryosphere"? Are you investigating ice-free areas or the cryosphere? Do you project the expansion of ice-free areas? Please be precise.
l. 27 What do you mean by "most climate extremes"? Extremes could be extreme warm or cold temperatures, extreme precipitation, extreme aridity... Please be precise.
l. 28 Which ice-free regions? McMurdo Dry Valleys, parts of Victoria Land, Larsemann Hills, etc. are also ice-free and do not play a role in your work. That means to speak of "ice-free regions of Antarctica" in general is way too far-fetched.
l. 29 What do you mean by "the impact of this carbon sink"? The extent of it? Its impact on what?
l. 31 Which factors besides temperature and precipitation did you investigate? Which had no impact on SOC stocks?

Main
l. 34 The given reference (1) does not investigate warming at AP or MA. In addition, a more recent reference should be added here.
l. 35 The given reference (2) suggests that Antarctica served as a C sink during the late Palaeocene/early Eocene.
l. 37 What do you mean by "soil storage"? References (4) and (5) focus explicitly on MA and/or King George Island - this does not refer to Antarctica as a whole.
l. 38 "SOCs"?
l. 41 "hazardous scenarios" does not sound appropriate
l. 37-43 Please review this whole sentence and split it at least into two sentences.
l. 43 Context with the given references (9), (10), and (11) is not clear. Do you want to show that there is no data about Antarctic soils? Please make this clear, especially for (11).
l. 49 It is not clear why you added reference (6) here.
l. 55 Why did you add reference (21) here? Where is the connection to active layer depths?
l. 56 What is the connection between the references (13) and (22) and the prediction of SOC stocks over time and their correlation with climate change? Both studies have a completely different focus.
l. 57-59 What is the "influence of the Antarctic cryosphere" on SOC stocks that you refer to here? Do you assume there are C stocks frozen in the permafrost like in the Arctic? Is it the melting of ice shields? What is the point here? The studies

you named before didn't even have their focus on SOC stocks.
l. 61 I don`t think that "glaring omission" is a very appropriate term.
l. 63-66 "Uncertainties, insufficient information, and challenges"? This is way too imprecise for a scientific paper. What regional and global consequences do you have in mind?
l. 66-69 0,35% of the Antarctic continent is so far ice-free (Bockheim&Haus 2014) and Antarctica comprises less than 10% of the global land surface. Do you think a lack of knowledge regarding this area "pose obstacles to global warming mitigation strategies... and... constrain the accurancy of the overall long-term predictions of current climate change models"? It is without doubt necessary to investigate soil organic matter, soil development, and changes driven by climate warming in Antarctica, but your framing is not appropriate.
l. 70-77 You can not add here in the last sentence that the "primary areas of study focused on MA and the AP". First, ALL of your study focuses on MA and AP. Regarding the fact that MA and AP are very special regions with special conditions (see for instance Vaughan et al., 2003), you can not use them to draw conclusions on the whole continent.

Results
l. 81 Again, this is not Antarctica - this is MA and the tip of the AP with James Ross Island
l. 81-83 What is your first analysis? The prediction of the SOC stock at the present time? I am not sure if you should call a prediction an analysis. And why should a prediction of the present time account for SSP scenarios in the future?
l. 84 It reflects the predicted conditions of the present scenario? What do you mean - the status quo?
l. 93-104 It is obvious that if you have absolute values (Mg) the area has an impact. I don't understand why you explain this at length.
l. 127 "The quantities of SOC stocks stored or lost in the prediction our model..."?
l. 130-134 With this in mind you think it is appropriate to give statements about the whole of Antarctica?
Figure 3: It would increase the readability of the figure when you added information on the variables directly to the figure - or when you replaced the variables with meaningful abbreviations or terms.
l. 185-191 Did you at some point take into account that global warming will most probably increase ice-free areas?
l. 198 What is "active" periglacial erosion?
l. 197-206 What kind of audience do you want to address with this paper?
l. 197-211 Here are several references missing.
l. 212 If you are convinced that the reference (18) is needed, you should put it into context and not just write it down at the end of the paragraph.
l. 213-220 Vegetation/NPP is a difficult variable in this area. First, you cannot just expect that vegetation is there and plant litter contributes to the SOM/SOC. So far, vascular plants are only present on some islands in the region of MA and AP. That means, the proliferation of plant seeds etc. has to be taken into account - this is a huge difference compared to other regions. If this is not possible in your model, you have to address it. Second, you should be familiar with the greening/browning phenomenon also known from the Arctic. So far, it is not clear if vegetation reacts with expansion (and greening) to warming or if the increasing evaporation leads to dieback of the highly adapted organisms (browning). Please check for instance Robinson et al., 2018 and Amesbury et al., 2017.
Figure 4: What is the point of the thresholds here? Where do they derive from? What is the reason for the scale of annual precipitation? Where is the "Antarctic limit" in the map? Where do the colors of the scales reflect on the map? This whole figure needs to be revised and to be made clear. "The gradients of these three variables decrease from left to right"? If annual precipitation decreases from left to right, something is wrong with your scale.
l. 260-261 "Our results suggest a relationship between SOC stock values and increases in NPP"? This is a finding of your work?
l. 315-319 Please revise this sentence. Your reference (21) dates back to 2010 - don't you think that additional work has been done in the last 15 years? References (22) and (23) are unnecessary self-citations.

Discussion
l. 346 You have no information on soils in most parts of Antarctica in your study.
l. 353-379 Where does this comparison with the Arctic come from? How can you compare both regions, especially "certain regions of Antarctica" with "some regions of the Arctic"?
l. 375-379 This is only true if you do not have processes like cryoturbation etc. And I do not see why this should be relevant to your work.
l. 384-385 Colonization/expansion of plant communities is restricted to the proliferation of plant seeds etc. - this might be true for MA and AP where vascular plants are present, but not for other parts of Antarctica. Accordingly, reference (32) investigates soils on Stepping Stones on the west coast of the AP.
l. 392 Reference (33) investigates C uptake by lichens and bryophytes - lichens are no plants.
l. 392 Reference (34) - focusing on MA - concludes "A net loss of CO2 that was observed in the sites predominantly colonized by higher plants and without vegetation cover occurred due to higher mineralization processes associated with elevated soil temperature and absence of vegetation cover, respectively." I do not see the connection with your statement.
l. 394 Reference (5) investigates CO2 emissions, not SOC stocks.
l. 400 Do you think the authors of reference (41) were the first to investigate this relation? Please cite basic literature and avoid unjustified self-citations.
l. 402-409 As you exclusively study soils in MA and AP this whole part is not needed.
l. 409-412 Again, this is not true for Antarctic soils in general. And obviously, it does not play a role in your model?
l. 412-417 Where is the connection to your work? You repeat that soil depth plays a role regarding SOC stocks.
l. 422-423 First, where is the connection to central Spain here? Second, are you convinced the authors of reference (45) were the first to investigate this connection?

Conclusion

l. 435-436 This sentence perfectly outlines your work. If you write the whole manuscript according to it, it could work.
l. 450 Where do the "carbon-emitting areas in the Arctic" come from? What is the scientific reasoning behind this trade-off?

Methods
l. 455 Why "primary"?
l. 506 Is (64) the first time this method was described?
l. 510 "High stoniness"? Were the samples not sieved by 2mm before like it is usually done?

Reviewer #3 (Remarks to the Author):

Authors conducted a study across Antarctica using legacy data of soil observations, data of environmental factors and modeled climate scenario data with machine learning. Authors report that under future emission scenarios Antarctica will be a sink of atmospheric carbon. Though authors did a praiseworthy job in attempting to answer an important question, but I see several limitations in the current format of the manuscript.

The Abstract must mention how many soil profile sites authors used, which environmental factors data were used, and what was the predictive accuracy of the baseline SOC stocks of ML models in the form of R2 values.

Are the number of samples (n=2800) represent observation sites or total number of analyzed samples, please clarify. Also, provide write-up of how these samples/sites represent the environmental variability of your study area?

Reported R2 values (~0.29) are very poor and may not merit publication unless authors do a better job of employing a large number of environmental factors to increase the predictive accuracy of the used ML models. Also, I am surprised to see that authors did not use any studies which have attempted to answer the same question using similar methodologies in different parts of the world, for example:

Gautam, et al. 2022. Climate change may release over 1.8 petagrams of soil organic carbon from topsoils in the United States by 2100, Global Ecology & Biogeography, 31, 1146-1160, doi: 10.1111/geb.13489.

Wang, et al. 2022. Global soil profiles indicate depth-dependent soil carbon losses under a warmer climate, Nature Communications, 13, 5514, doi:10.1038/s41467-022-33278-w.

Wang et al. 2024. Responses of soil organic carbon to climate extremes under warming across global biomes, Nature Climate Change, 14, 98–105, doi:10.1038/s41558-023-01874-3.

I want authors to cite and discuss these previous findings as it relates or differs with their findings.

Version 1:

Decision Letter:

Dear Dr Mello,

Your manuscript titled "Global warming turns ice-free areas of Maritime and Peninsular Antarctica into soil organic carbon sinks" has now been seen by 3 reviewers, and we include their comments at the end of this message. They appreciate the revisions made thus far, but some points persist. We remain interested in the possibility of publishing your study in Communications Earth & Environment, but would like to consider your responses to these concerns and assess a revised manuscript before we make a final decision on publication.

We therefore invite you to revise and resubmit your manuscript, along with a point-by-point response that takes into account the points raised. Please highlight all changes in the manuscript text file.

Please submit your point-by-point responses as a separate file, distinct from your cover letter where you can add responses to the Editors' comments that you do not want to be made available to the reviewers. Word files are preferred.

Important: The response to reviewers must not include any figures, tables or graphs. If you wish to respond to the reviewer reports with additional data in one of these formats, please add them to the main article or Supplementary Information, and refer to them in the rebuttal. Due to current technical limitations, any figures, tables, or graphs embedded in your rebuttal will not be included in the peer review file, if published.

We are committed to providing a fair and constructive peer-review process. Please don't hesitate to contact us if you wish to discuss the revision in more detail.

Please use the following link to submit your revised manuscript, point-by-point response to the referees' comments (which should be in a separate document to any cover letter), a tracked-changes version of the manuscript (as a PDF file) and the completed checklist:
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** This url links to your confidential home page and associated information about manuscripts you may have submitted or be reviewing for us. If you wish to forward this email to co-authors, please delete the link to your homepage first **

We hope to receive your revised paper within six weeks; please let us know if you aren't able to submit it within this time so that we can discuss how best to proceed. If we don't hear from you, and the revision process takes significantly longer, we may close your file. In this event, we will still be happy to reconsider your paper at a later date, as long as nothing similar has been accepted for publication at Communications Earth & Environment or published elsewhere in the meantime.

Please do not hesitate to contact us if you have any questions or would like to discuss these revisions further. We look forward to seeing the revised manuscript and thank you for the opportunity to review your work.

Best regards,

Alice Drinkwater, PhD
Associate Editor
Communications Earth & Environment
@CommsEarth

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We ask that you ensure your manuscript complies with our editorial policies. Please ensure that the following formatting requirements are met, and any checklist relevant to your research is completed and uploaded as a Related Manuscript file type with the revised article.

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All Communications Earth & Environment manuscripts must include a section titled "Data Availability" at the end of the Methods section or main text (if no Methods). More information on this policy, is available at http://www.nature.com/authors/policies/data/data-availability-statements-data-citations.pdf.

In particular, the Data availability statement should include:
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- If applicable, a statement regarding data available with restrictions
- If a dataset has a Digital Object Identifier (DOI) as its unique identifier, we strongly encourage including this in the Reference list and citing the dataset in the Data Availability Statement.

DATA SOURCES: All new data associated with the paper should be placed in a persistent repository where they can be freely and enduringly accessed. We recommend submitting the data to discipline-specific, community-recognized repositories, where possible and a list of recommended repositories is provided at http://www.nature.com/sdata/policies/repositories.

If a community resource is unavailable, data can be submitted to generalist repositories such as figshare or Dryad Digital Repository. Please provide a unique identifier for the data (for example a DOI or a permanent URL) in the data availability statement, if possible. If the repository does not provide identifiers, we encourage authors to supply the search terms that will return the data. For data that have been obtained from publically available sources, please provide a URL and the specific data product name in the data availability statement. Data with a DOI should be further cited in the methods reference section.

Please refer to our data policies at http://www.nature.com/authors/policies/availability.html.

REVIEWER COMMENTS:

Reviewer #1 (Remarks to the Author):

The authors have accepted almost all the suggestions and corrections. With the changes introduced, I believe the focus of the work has improved significantly. Both the additional information in the introduction and in the discussion greatly enrich the work. I want to congratulate the authors on the work done. Although they did not include a white polygon on Deception Island, I understand that the map's scale is very general and that it might appear too small. However, I personally think it would be worth the effort. My cartographic training makes me continue to interpret this omission as an error, but I accept the authors' arguments.
I would like to comment on a few things:
- # Line 83-84: "Even for the most advanced and recent studies modelling SOC stocks, Antarctic ice-free areas remain a significant gap….."
I disagree with this statement; there is some recent work that models the distribution of DOC in the Byers Peninsula that could be cited. It's just a suggestion since I am the author of that work, so I don't feel it's appropriate to insist on citing it, but I would like them to do so.
Fernandez, S.d.C., Muñiz, R., Peón, J., Rodríguez-Cielos, R., Ruız, J., Calleja, J.F., (2024) Mapping dissolved organic carbon and organic iron by comparing deep learning and linear regression techniques using sentinel-2 and worldview-2 imagery (byers peninsula, maritime antarctica). Remote Sensing 16. URL: https://www.mdpi.com/2072-4292/16/7/1192, doi:10.3390/rs16071192.

- # New Title: "Global warming turns ice-free areas of Maritime and Peninsular Antarctica into soil organic carbon sinks"
I disagree with the new title. Although it's true that the model was developed using samples from those areas (Maritime and Peninsular Antarctica), I believe that the model and its predictions are valid for the entire Antarctic region. I preferred the original title, although I understand that the change was made to address another reviewer's corrections. However, the model is indeed valid for any other ice-free location in Antarctica... and it's a shame that the title cannot reflect that global predictive nature.
Below, I suggest some alternative titles, one of which attempts to reflect the model's uncertainty... which is not insignificant
- Predicting Soil Carbon Sequestration in Ice-Free Regions of Maritime and Peninsular Antarctica Under Intensified Climate Change Scenarios.
- Predicting Soil Carbon Storage in Ice-Free Regions of Antarctica Under Climate Change
- Global warming may turn ice-free areas of Maritime and Peninsular Antarctica into potential soil organic carbon sinks

Reviewer #2 (Remarks to the Author):

This is the revised version of the authors' study. They use a modelling approach to evaluate the effect of global warming on SOC stocks in Maritime Antarctica under different climate change scenarios. The authors made some effort to react to the reviewers' comments and the manuscript somehow improved. However, there are still some concerns regarding the quality of the manuscript: Regarding the given references - I already commented on many references that did not fit the given statements in my first review. Now again, several references are already in the first paragraphs that do not fit. I stopped commenting on references from line 52 on. To achieve a manuscript that can be published, the authors should thoroughly check all the references they use and take care that they are appropriate. This is an integral part of scientific work. Regarding self-citations, there is no restriction for citing your work, but you should be careful and the references should fit very
well - self-citations in the wrong context leave a bad impression and can negatively impact the reception of your work. I understand that you want to highlight that your group is "among the most active contributors to Antarctic soil science", but this can primarily be achieved by sound scientific work. In addition, your list of references should be checked in detail - some are given with all co-authors, some only with the main author et al. You have a limit of 50 references but give 97 references. A major concern is the Discussion - in most parts, the authors do not discuss their results, but focus on other researchers' work and bring up completely new topics. The Discussion needs to be completely revised. Another major concern is that several parts of the manuscript are still too wordy and contain redundant information and parts of the manuscript still need to be more precise. The Results section should be structured more clearly, parts of it are redundant and should be tightened.

Please see my detailed comments below (line numbers refer to the revised manuscript without changes marked):

Title
The new title fits the scope of your work much better. However, as your predictions are based on modeling, I suggest attenuating it slightly by adding "most probably" or "Global warming has the potential to..." or something similar.

Abstract
l. 21 I suggest to use "stocks" (plural) here.
l. 29 Do you mean the Chelsa database?
l. 34 I suggest adding future tense here, for instance "...are going to increase..."
l. 36 Same here, I suggest emphasizing the future aspect more.
l. 36/37 I suggest replacing "intensity of the soil carbon sink" with a better fitting term - if I get it right, you are interested in how much the C sinks increase.

Main
l. 41/42 "The Island of Maritime Antarctica..." is not correct. Should be "The islands of Maritime Antarctica..." Do you mean the Eastern AP or the islands east of the AP?
l. 43 Please be precise. Adams et al. state that the AP showed rates of warming that are "some of the fastest measured in the Southern Hemisphere". Same with Vaughan et al. - they identified three regions of recent rapid regional warning, with the AP being one of them. That does not mean that the AP "is experiencing the most rapid warming... in the world". In addition, I suggest to refer to original references (in case of Adams et al.) and to references that are more recent.
l. 43/44 Again, the reference (Gray et al.) does not fit here. The authors investigated the role of green snow algae and their carbon sink in the AP region - there is no connection with the whole of Antarctica becoming a C sink.
l. 45-47 What is your statement here? What is the relation to Arctic ecosystems? Already in my first review, I wondered what you mean by SOCs - and did not receive an answer. The s implies a plural that does not make sense - soil organic carbons? Please revise this sentence.
l. 51 Smith et al investigate the glacial organic C pool in the McMurdo Dry Valleys and Benavent-Gonzalez et al. the interplay between vegetation and soil functioning.
From this point on I stop commenting on your references. I expect you to thoroughly check all your references and revise your manuscript accordingly to achieve a manuscript that is fit for publication.
l. 52 Where is the connection between your work and East Antarctic soils?
l. 55 What do you mean by "limited in number"? Number of species? Number of individuals?
l. 56-58 Carbon also accumulates elsewhere under warm conditions, please revise this sentence.
l. 59 Do you count bird droppings as marine source of organic material? Please be precise.
l. 60-62 What about non-native vascular plants?
l. 68 It should be "...data from the harsh and..."
l. 67-71 Please rephrase this sentence.
l. 86-87 "...the potential of current ice-free areas... to increase carbon stocks"? This sounds strange. Please rephrase and re-check the whole sentence.
l. 89-91 I do not see why this is relevant here.
l. 100 Again, do you mean the Chelsa database? If not, please explain what you mean by Chelsea.

Results
l. 107 "compose MA and AP"? The AP is not composed of islands and as your work does not cover all islands in the region I suggest rephrasing this sentence accordingly, for instance "...different islands in the region of MA and AP". In addition, it would be good to give precise information on "different islands" - how many?
l. 108-111 Please rephrase and shorten: "...currently... at the present time" and "...of the present moment" is redundant.
l. 120-130 This passage is way too wordy, please shorten it. You can address the impact of the area in one sentence.
l. 139-152 I suggest using increase (singular) instead of increases throughout the manuscript. In addition, I suggest using different words to enhance readability - this passage alone contains seven times the words increase and increases.

l. 139/140 I suggest rephrasing this sentence: "Our model predicts a substantial increase of SOC stocks for all three SSP scenarios." or something similar.
l. 140-148 You can shorten this part. How can SOC increments have a direct proportional relationship with temperature increments when you have a decrease in SOC stocks in some islands? You should name that you first look at the whole region and afterward at the single islands.
l. 154/156 "are predicted to increase/decrease their SOC stocks" sounds like the islands are acting willfully. Please rephrase.
l. 169 "considering all the SSPs global warming scenarios"? Are you considering all scenarios here now or the three you named before? Please be precise.
l. 204-211 Please rephrase this passage and clarify it - at the moment it is rather confusing.
l. 211-217 Too wordy.
l. 220 Why "elevation or height"? One term is enough.
l. 218-222 Too wordy. Suggestion: "The variable ridge level (RL), which refers to the elevation of a ridge, explains 100% of the predicted SOC stocks within the surface layer. High RL indicates a proneness to erosion which significantly influences..."
l. 222 "especially in periglacial-semiarid pedogeomorphic systems"? Is there a substantially different effect of erosion compared to other systems?
l. 224 Already in my first review I asked what you mean by "active" periglacial erosion - you explained periglacial erosion and added the respective information, but you did not answer my question. Is there a passive periglacial erosion? In other words: do you need the word "active" here?
l. 230 I intended to stop commenting on references, but why did you reference the work of Walker et al. about calcium-rich Arctic (!) steppe here? In addition, information on colluvial soils has been available for much longer than 2001.
l. 235 Reference (31) is not needed.
l. 236 What does "these areas" refer to? The flat terrains? This is confusing as you go back to RL in line 238.
l. 237 "hinder the presence of vegetation"? Rather "hinder the establishment of vegetation" or something similar.
l. 238-241 I don't think that this part is relevant, but if you want to keep it you should shorten it and put it at the beginning of the RL passage.
l. 244-246 This is trivial and you should not name it as one of your findings.
l. 248 Did you include the proliferation of ice-free areas in your model?
Figure 4: I may repeat my comment from my first review: "What is the point of the thresholds here? Where do they derive from? What is the reason for the scale of annual precipitation? Where is the "Antarctic limit" in the map? Where do the colors of the scales reflect on the map? This whole figure needs to be revised and to be made clear. "The gradients of these three variables decrease from left to right"? If annual precipitation decreases from left to right, something is wrong with your scale." In your answer, you said you revised the figure according to another reviewer's suggestions. The only change I see is that you changed the colors for NPP.
l. 292/293, 313/314 etc. You repeat several times that your results indicate that climate change could enhance the potential of Antarctic ice-free soils to act as carbon sinks. Please remove the repetitions and take care that the complete Results section becomes tighter.
l. 318/319 This is not a special feature of MA or AP.
l. 319-321 Please revise this sentence. This is a very general statement, especially guano phosphatization plays only a role in soils where seabird colonies are present.
l. 323-326 Please make clear where the connection to your work is and shorten it.
l. 330 Again, invasive plants do not contribute to SOC?
l. 323-333 Please shorten this passage and indicate the connection to your work.
l. 333 Reference (12) is not needed.
l. 336 "...across the areas the studied site"?
l. 340-345 This statement needs solid references. You should check the work of Molina-Montenegro et al. (2019), Bergstrom (2022), Tichit et al. (2024). Especially in the AP and MA region, invasive species should not be neglected.
l. 352-353 It is not clear what these uncertainty values refer to as you name uncertainty values for SOC stocks in the following sentence.
l. 397-398 This is redundant - both the statement and the sentence.
l. 398-401 Again repetitive. Warmer temperatures can also have a negative effect on plant growth, please address this.
l. 401, 403 These are general statements that require general references.
l. 404 You give a reference from 1985 to underline the current colonization?
l. 404-410 Too wordy.
l. 427 You should add short information what negative carbon-climate feedback means (you don't have to repeat the explanation in the Discussion section).
l. 431 What do you mean by "are poised"?

Discussion
l. 442 You use a modeling approach, please attenuate your statements accordingly. "...will be..." indicates that this will happen for sure.
l. 449-461 I still don't see why you need the comparison with the Arctic here. However, if you are convinced you need it, you should massively shorten this passage. I don't see any additional value here in trying to counterbalance the Arctic with its massive C stocks with the rather small ice-free areas in the MA and AP region. Please stick to your recent work and discuss your results.
l. 462-476 Again, please stick to your recent work and discuss your results. The SOC stocks of the Arctic are not related to your work.
l. 481-483 You stated that you could not include data on the proliferation of ice-free areas in your model?

l. 483-498 Please discuss your results and not other researchers' work.
l. 499-512 Same here.
l. 521 Why did you not add this in the limitations section?
l. 537-549 This is not the place to introduce new topics. Why do you mention the soil texture of your samples for the first time here in the last paragraph? You should discuss your results here, but you introduce a completely new topic.

Conclusion
l. 551 Again, it is not appropriate to use "will" here.
l. 564-570 Again, focus on your recent work - the comparison with the Arctic is not appropriate here as it does not conclude any aspect of your work.

Methods
l. 580/581 Please give a reference here.
l. 581 "hovering"?
l. 581 "carpets moss"?
l. 581/582 Please give a reference here.
l. 582-584 Please give a reference here.
l. 584-586 Please give a reference here.
l. 599 It should be "World Reference Base for Soil Resources"
l. 628-630 Please rephrase this sentence.

Reviewer #3 (Remarks to the Author):

Authors have appropriately addressed my comments and included my suggestions in the revised manuscript. I do not have any further concerns with this manuscript.

Version 2:

Decision Letter:

Dear Dr Mello,

Your revised manuscript titled "Global warming may turn ice-free areas of Maritime and Peninsular Antarctica into potential soil organic carbon sinks" has now been overseen by our editorial team. We are delighted to say that we are happy, in principle, to publish a suitably edited version in Communications Earth & Environment.

We therefore now invite you to edit your manuscript to comply with our format requirements and to maximise the accessibility and therefore the impact of your work.

EDITORIAL REQUESTS:

Please review our specific editorial comments and requests regarding your manuscript in the attached "Editorial Requests Table".

*****Please take care to match our formatting and policy requirements. We will check revised manuscript and return manuscripts that do not comply. Such requests will lead to delays. *****

Please outline your response to each request in the right hand column. Please upload the completed table with your manuscript files as a Related Manuscript file.

If you have any questions or concerns about any of our requests, please do not hesitate to contact me.

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We hope to hear from you within two weeks; please let us know if you need more time.

Best regards,

Alice Drinkwater, PhD
Associate Editor
Communications Earth & Environment
@CommsEarth

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The manuscrip titled “Global warming drives Antarctica to become a soil organic carbon sink” aims to assess the potential impacts of global warming on SOC under three Shared Socioeconomic Pathways, using an integrated methodology that combines soil field data, machine learning, and future climate change scenario projections for the Antarctic cryosphere. Focusing on the 0–30 cm soil layer, the research findings indicate that most climate extremes lead to an increase in SOC stock (from 359 ± 146 Mg to 686 ± 197 Mg), suggesting that ice-free regions in Antarctica might act as carbon sinks. The study also finds that the predicted SOC stocks are primarily influenced by temperature and precipitation, which are linked to net primary productivity. In summary, studying how climate change could affect SOC reserves in Antarctica.

The manuscript is well structured, the citations, although they could be improved, are adequate. Almost all the figures are of high quality. I consider this manuscript to be suitable for the journal. My general opinion is that it is a carefully crafted manuscript, it deals with a very important topic and it does so in a novel way. However, I consider that the authors should make some important changes and even introduce new topics. These new issues are very important to understand how Antarctic ecosystems and soils may evolve with climate changet and could limit the applicability of this study.

Main concerns

1: The Soil Organic Carbon (SOC) in Antarctica primarily originates from several limited sources due to the continent's extreme conditions. Here are the main contributions to organic carbon in Antarctic soils: 1-Microorganisms: Most of the organic carbon in Antarctic soils comes from microorganisms such as bacteria, algae, and fungi. These organisms are capable of surviving in extreme conditions and play a crucial role in the production and decomposition of organic matter. 2-Lichens and Mosses: Although limited in number, lichens and mosses significantly contribute to the soil organic carbon in Antarctica. These organisms decompose very slowly due to low temperatures, allowing carbon to accumulate in the soil. 3- Marine mamals and Bird Deposits: In some coastal areas, deposits of organic material can come from marine sources like seaweed washed a shore and bird droppings (guano), which are rich in organic carbon and nutrients. Vascular Plants: The two native vascular plant species, *Deschampsia antarctica* and *Colobanthus quitensis*, although limited in distribution, also contribute to SOC through the deposition of their plant residues, which are decomposed by microorganisms. And perphas wind-Deposited Organic Material: Organic material can be transported to Antarctica through air currents. This material includes spores, pollen, and small fragments of plants from other parts of the world.

2: The authors of this paper have overlooked that a significant portion of the current SOC primarily originates from the usage of ice-free areas by fauna (marine mammals and birds) during the summer. Although predictive models suggest future colonization by vegetation, the geographical isolation of Antarctica poses a significant barrier. Even with

changes in temperature and precipitation, the introduction of plant species other than Deschampsia antarctica (Antarctic hairgrass) and Colobanthus quitensis (Antarctic pearl grass), both of which contribute to soil carbon, may not take place. If the authors don't see a way to include these variables in their models, they should at least take it into account in the discussion. Antarctica cannot be treated like other areas of the planet with less isolation.

3: There should be important consideration of this source of uncertainty as it is not known how the rise in temperature would affect the behaviour of fauna. It is quite possible that many of these species that use the coasts of ice-free islands in summer have substantial changes in their behavior (see https://doi.org/10.3390/rs16071192). It has a lot of cartographic information about the areas with faunal pressure. Also, in QAntartica the authors can find maps about the áreas under hight wildlife presure.

4: Another problem is in the definition of ice-free areas. Deception Island is considered to be ice-free and that's not true at all. 2/3 of Deception Island is ice cap (see for example Mount Pond or Irizart). This makes the carbon concentration vastly underestimated and all calculations made for Deception Island are affected by this error. In addition, Deception Island is used very intensively by wildlife in summer. Authors should correct these errors in the new versión.

5: Although the figures are of high quality and all of them necessary. Figure 4 needs to be reworked, because what the authors explain in the footer is not apparent in the figure. Authors could transform graphical scales into maps. Precipitation; temperature and PPN. Also, at the bottom of the figure they say that you see a correlation between SOC and PPN but it is not entirely true, especially in James Ross and Seymur islands. These areas show high concentration of SOC.

Minor concerns

6: Figure 5 should also show the relationship between the BIO13 variable and the increase in SOC.

7: Authors should also order the bibliographic citations: lines 37 contains citation number 5 and on line 43 is citation 9; 6, 7 and 8 are missing. Check if appointments are missing or out of order

REVIEWER COMMENTS:

Reviewer #1 (Remarks to the Author):

The manuscript titled "Global warming drives Antarctica to become a soil organic carbon sink" aims to assess the potential impacts of global warming on SOC under three Shared Socioeconomic Pathways, using an integrated methodology that combines soil field data, machine learning, and future climate change scenario projections for the Antarctic cryosphere. Focusing on the 0–30 cm soil layer, the research findings indicate that most climate extremes lead to an increase in SOC stock (from 359 ± 146 Mg to 686 ± 197 Mg), suggesting that ice-free regions in Antarctica might act as carbon sinks. The study also finds that the predicted SOC stocks are primarily influenced by temperature and precipitation, which are linked to net primary productivity. In summary, studying how climate change could affect SOC reserves in Antarctica.

A: *No action is required.*

The manuscript is well structured, the citations, although they could be improved, are adequate. Almost all the figures are of high quality. I consider this manuscript to be suitable for the journal. My general opinion is that it is a carefully crafted manuscript, it deals with a very important topic and it does so in a novel way. However, I consider that the authors should make some important changes and even introduce new topics. These new issues are very important to understand how Antarctic ecosystems and soils may evolve with climate change and could limit the applicability of this study.

Main concerns

1: The Soil Organic Carbon (SOC) in Antarctica primarily originates from several limited sources due to the continent's extreme conditions. Here are the main contributions to organic carbon in Antarctic soils: 1-Microorganisms: Most of the organic carbon in Antarctic soils comes from microorganisms such as bacteria, algae, and fungi. These organisms are capable of surviving in extreme conditions and play a crucial role in the production and decomposition of organic matter. 2-Lichens and Mosses: Although limited in number, lichens and mosses significantly

contribute to the soil organic carbon in Antarctica. These organisms decompose very slowly due to low temperatures, allowing carbon to accumulate in the soil. 3- Marine mamals and Bird Deposits: In some coastal areas, deposits of organic material can come from marine sources like seaweed washed a shore and bird droppings (guano), which are rich in organic carbon and nutrients. Vascular Plants: The two native vascular plant species, Deschampsia antarctica and Colobanthus quitensis, although limited in distribution, also contribute to SOC through the deposition of their plant residues, which are decomposed by microorganisms. And perphas wind-Deposited Organic Material: Organic material can be transported to Antarctica through air currents. This material includes spores, pollen, and small fragments of plants from other parts of the world.

A: *We agree with the reviewer that Soil Organic Carbon (SOC) in Antarctica primarily originates from a few limited sources due to the continent's extreme conditions. Based on this comment, we have added a fully referenced paragraph in the introduction and another in the discussion section of the paper, highlighting these different sources. Additionally, we have included a paragraph addressing the limitations of our model concerning this issue.*

Introduction: *"The main contributions to SOC in East Antarctic soils include various sources such as microorganisms such as cyanobacteria and blue-green algae(Gajananda, 2007), and fungi(Newsham et al., 2018), which are capable of surviving in extreme conditions and play a crucial role in the production and decomposition of organic matter(Smith et al., 2017). Although limited in number, lichens and mosses significantly contribute to soil organic carbon in Antarctica(Benavent-González et al., 2018). These organisms decompose very slowly due to low temperatures, allowing carbon to accumulate in the soil. In some coastal areas, deposits of organic material can come from marine sources like seaweed washed ashore and bird droppings (guano), which are rich in organic carbon and nutrients(Bockheim and Haus, 2014). The two native vascular plant species, Deschampsia antarctica and Colobanthus quitensis, although limited in distribution, also contribute to SOC through the deposition of their plant residues(Thomazini et al., 2016), which are decomposed by microorganisms. Additionally, organic material can be transported to Antarctica through air currents(Elberling et al., 2006). This material includes spores, pollen, and small fragments of plants from other parts of the world."*

Discussion:

2: The authors of this paper have overlooked that a significant portion of the current SOC primarily originates from the usage of ice-free areas by fauna (marine mammals and birds) during the summer. Although predictive models suggest future colonization by vegetation, the geographical isolation of Antarctica poses a significant barrier. Even with changes in temperature and precipitation, the introduction of plant species other than Deschampsia antarctica (Antarctic hairgrass) and Colobanthus quitensis (Antarctic pearl grass), both of which contribute to soil carbon, may not take place. If the authors don't see a way to include these variables in their models, they should at least take it into account in the discussion. Antarctica cannot be treated like other areas of the planet with less isolation.

A: *We thank the reviewer for pointing out these limitations. We have addressed these issues by including a detailed sentence in the limitations section of our manuscript, discussing these limitations and highlighting them as suggested. Additionally, we have incorporated the references provided by the reviewer to support this discussion as following:*

"Plant biomass inputs in surface soils play a crucial role in changes to SOC stock. The retreating glaciers expose new areas for plant colonization, while warmer temperatures enhance the plants' growth (Tang and Baldocchi, 2005). This expansion leads to rapid soil development, with increased vegetation cover correlating with higher levels of SOC, nitrogen, and organic matter in the soil(Strauss et al., 2009). The expansion of plant communities can further enhance NPP and, consequently, influence SOC stocks. However, it is important to note that the areas currently colonized by vascular plants in MA and AP are limited to a few locations(Komárková et al., 1985). For new areas in MA and AP to be colonized in response to increases in temperature and nutrient availability, and for subsequent contributions to SOC transport and stock, it is essential for plant propagules to reach these new areas. This represents a limitation of our models, as we were unable to incorporate data on plant propagules or trends in vegetative propagation for future scenarios due to the lack of publicly available data on the dynamics of vegetative propagule dispersal. Furthermore, a simple increase in NPP does not necessarily mean that new ice-free areas will be colonized by plant communities and, as a result, see increases in SOC stocks. Temperature increases could lead to extreme

climate conditions as colder and harsher winters, potentially resulting in reduced snowmelt and increased aridity in some areas(Robinson et al., 2018). This could restrict plant colonization and result in either greening or browning of the landscape. Therefore, it remains unclear whether vegetation in MA and AP will expand (and greening) in response to warming or if increased evaporation will cause dieback of highly adapted organisms (browning)(Amesbury et al., 2017; Robinson et al., 2018). Additionally, it was not possible to include these factors as predictor variables in our models for SOC stock."

3: There should be important consideration of this source of uncertainty as it is not known how the rise in temperature would affect the behaviour of fauna. It is quite possible that many of these species that use the coasts of ice-free islands in summer have substantial changes in their behavior (see https://doi.org/10.3390/rs16071192). It has a lot of cartographic information about the areas with faunal pressure. Also, in Antartica the authors can find maps about the areas under hight wildlife pressure.

A: *Dear reviewer, we acknowledge that while there are existing maps indicating fauna pressure in certain regions of Antarctica, it is currently not feasible to predict the behavior of regional fauna within our models. Moreover, there is a lack of a comprehensive database at the regional level that could be incorporated into the model, as well as data on fauna behavior and pressure for future SSP periods. We recognize this as another limitation of our study and have added a paragraph addressing this in the limitations section as following:*

"SOC stock levels and NPP are also influenced by the biological activity of regional fauna, particularly penguins in areas where Pygoscelis species are present, as their excrement significantly contributes to the organic matter(Bockheim and Haus, 2014; Zhu et al., 2014). The behavior of fauna in MA and AP has been impacted by global warming, leading to rapid demographic changes in some penguin populations and affected areas(Peña M et al., 2014; Sander et al., 2007). However, incorporating animal behavior data into our models was not feasible, as there is no sufficiently detailed fauna behavior database at the regional level, nor future projections considering SSP periods. This is another limitation of our study."

4: Another problem is in the definition of ice-free areas. Deception Island is considered to be ice-free and that's not true at all. 2/3 of Deception Island is ice cap (see for example Mount Pond or Irizart). This makes the carbon concentration vastly underestimated and all calculations made for Deception Island are affected by this error. In addition, Deception Island is used very intensively by wildlife in summer. Authors should correct these errors in the new version.

A: *Dear reviewer, note that the map presented in the paper, showing Deception Island and other small islands as completely ice-free, is merely illustrative. The scale of the map does not allow for the visualization of areas covered by ice sheets and snowbanks on small islands. Consequently, the map does not detail or include the small patches of mountain glaciers that are not cartographically representable on this generic map, as they do not meet the minimum mappable area. However, we ensure you that the original scale of the soil data and terrain-derived attributes used as predictive variables for SOC stocks in the model did consider the reality of the ice-free areas on a case-by-case basis.*

To prevent any confusion for future readers, we have added an additional caption addressing this issue below each figure (figures 3 and 4 in Extended data figures and tables).

5: Although the figures are of high quality and all of them necessary. Figure 4 needs to be reworked, because what the authors explain in the footer is not apparent in the figure. Authors could transform graphical scales into maps. Precipitation; temperature and PPN. Also, at the bottom of the figure they say that you see a correlation between SOC and PPN but it is not entirely true, especially in James Ross and Seymur islands. These areas show high concentration of SOC.

A: *Thank you for your detailed feedback. We have revised Figure 4 as per the suggestions. The figure has been updated for better clarity. The thresholds in Figure 4 were now stablished in all areas evaluated. The 'Antarctic regions (AP and MA) limit' is now clearly indicated on the map in. We have added a label for clarity. The scale for annual precipitation was chosen to represent the amount of precipitation of different regions trying to show a climatic gradient, ensuring that the data is represented accurately across different regions. Also, we have revised the color scale to ensure that it accurately reflects the corresponding data on the map. The statement regarding the*

gradients has been revised for accuracy. We have ensured that the annual precipitation scale is consistent with the direction of the gradients.

In addition to the modifications requested by the two reviewers, we addressed the two issues they pointed out (which effectively contributed to improving the work) and created three additional figures that illustrate the climatic and NPP gradients between the islands in detail. These figures have been added to the "extended data" section, with appropriate references to them in the text, so that future readers can access the detailed information.

"Consequently, temperature and precipitation exhibit a declining climatic gradient from north to south, which also aligns with a decrease in the NPP gradient (Figures 5, 6 and 7, extended data). However, the MA shows a more homogeneous pattern of precipitation and temperature due to the islands being relatively aligned longitudinally, which results in consistent patterns of NPP. (Figures 5, 6 and 7, extended data)."

Minor concerns

6: Figure 5 should also show the relationship between the BIO13 variable and the increase in SOC.

A: *We agree, and Figure 5 has been adjusted as requested to include BIO 13, along with the corresponding figure legend.*

7: Authors should also order the bibliographic citations: lines 37 contains citation number 5 and on line 43 is citation 9; 6, 7 and 8 are missing. Check if appointments are missing or out of order.

A: *Dear Reviewer, we acknowledge the minor errors in the order of references and the lack of a logical sequence. It is worth mentioning that we use Mendeley for referencing the manuscript, and sometimes errors occur for various reasons. However, we have reviewed and corrected the references as requested by the reviewer.*

Reviewer #2 (Remarks to the Author):

The authors use a modeling approach to evaluate the effect of global warming on SOC stocks in Antarctica under three different climate change scenarios. The major concern regarding this manuscript is the discrepancy between the title (whole "Antarctica") and the region they investigate (Maritime Antarctica and the Antarctic Peninsula, see Fig. 3). The approach to project from one small region to the whole continent is not eligible. The authors themselves address the "high spatial heterogeneity of the Antarctic environments" - so they should know that it is not appropriate to project results from one rather special part to the whole continent. In addition, the authors juggle with buzzwords, and especially the Introduction lacks in large parts clear content. Regarding references, it is often not clear why the authors chose the respective ones. Moreover, they tend to excessive self-citations and neglect other authors' work. However, in some parts, references are lacking. The whole manuscript reads in large parts not like the outcomes of scientific work, but like a description of what has been done (not only in the Method part where it belongs), explanations often seem to aim not at a scientific audience. In addition, large parts are not precise enough. Parts of the manuscript are wordy and the Discussion contains a large part about Arctic soils that do not fit here, especially not to this extent. A major part of the Discussion are factors and variables that were/could not be taken into account in the model but have a pronounced effect on SOC. However, also a "Limitations and uncertainties" section exists. The manuscript is therefore not well structured and needs to be revised completely. This work is not fit to be published in Communications Earth & Environment. See my detailed comments below:

A: *We agree with the reviewer that the title was inappropriate and have made the necessary adjustments based on the reviewer's observations. The title has been adapted to accurately reflect the scope of our work, specifically focusing on the Antarctic Maritime and the Antarctic Peninsula as following:*

"Global warming turns ice-free areas of Maritime and Peninsular Antarctica into soil organic carbon sinks"

Please we are open to suggestions and if the reviewer has any please let us know.

Abstract

l. 21 I suggest replacing "from global warming" with "driven by global warming" or something similar.

A: *The sentence was adjusted following the reviewer's recommendations.*

l. 21 Please be precise regarding the term "climate extremes" - are you investigating the effect of warming or extreme events?

A: *The sentence was adjusted following the reviewer's recommendations. We replace the climate extremes by climate change.*

l. 26 "for the Antarctic cryosphere"? Are you investigating ice-free areas or the cryosphere? Do you project the expansion of ice-free areas? Please be precise.

A: *The sentence was adjusted following the reviewer's recommendations. We replace the Antarctic cryosphere for Maritime and Peninsular Antarctic ice-free areas.*

l. 27 What do you mean by "most climate extremes"? Extremes could be extreme warm or cold temperatures, extreme precipitation, extreme aridity... Please be precise.

A: *The sentence was adjusted following the reviewer's recommendations and we were more precise as following: "Our models reveal that the effects of climate change, primarily changes in temperature and precipitation, result in an increase in SOC stock ..."*

l. 28 Which ice-free regions? McMurdo Dry Valleys, parts of Victoria Land, Larsemann Hills, etc. are also ice-free and do not play a role in your work. That means to speak of "ice-free regions of Antarctica" in general is way too far-fetched.

A: *The sentence was adjusted following the reviewer's recommendations. We replace the ice-free regions of Antarctica by "... indicating that ice-free regions of Maritime and Peninsular Antarctica tend to ...".*

We would like to clarify that we did not use data from the McMurdo Dry Valleys, parts of Victoria Land, or the Larsemann Hills, as these locations fall into different bioclimatic contexts—polar arid areas with little or no vegetation, characterized by salinized polar desert soils with minimal microbial biomass and cryptogamic cover. This study focuses on the sink potential of the warmer and more humid areas of Antarctic Maritime and the Antarctic Peninsula, and does not apply to continental Antarctica. Therefore, we have no intention of generalizing the observed trends from Maritime and Peninsular Antarctica to the extensive ice-free areas of continental Antarctica.

l. 29 What do you mean by "the impact of this carbon sink"? The extent of it? Its impact on what?

A: *We have revised the sentence to clarify and prevent confusion for future readers, as well as to address the issue raised by the reviewer. We replaced the word "impact" with "intensity" and made the following minor adjustments: "... the intensity of the soil carbon sink is contingent upon the existing soil organic carbon content and soil depth."*

l. 31 Which factors besides temperature and precipitation did you investigate? Which had no impact on SOC stocks?

A: *Dear Reviewer, in addition to temperature and precipitation, the contributions of morphometric variables were investigated, as described in the methodology. However, these variables were less significant in the modeling and did not appear in the variable importance rankings. Additionally, we apologize for the oversight in not including the table related to the morphometric variables of the relief in the supplementary material. This has now been corrected, and a new table with the appropriate adjustments has been attached.*

""We organized an environmental predictor explanatory database that included eight bioclimatic variables (BIO 1 = annual mean temperature; BIO 4 = temperature seasonality (standard deviation × 100); BIO 5 = maximum temperature of the warmest month; BIO 6 = minimum temperature of the coldest month; BIO 12 = annual precipitation; BIO 13 = precipitation of the wettest month; BIO 14 = precipitation of the driest month; and BIO 15 = precipitation seasonality), vegetation (NPP), and relief (a

digital elevation model and derived relief morphometric variables) (Table 3, extended data)."

Table 3: bioclimatic and relief data (morphometric variable) used as input data in SOC stock modeling processes

Predictor	Group	Importance (%)	Soil depth (cm)	Abbreviation
Precipitation Seasonality	Climatic	100	0-5	BIO 15
Ridge Level	Relief	99,8	0-5	RL
Precipitation of Driest Month	Climatic	92,1	0-5	BIO 14
Precipitation of Wettest Month	Climatic	73,4	0-5	BIO 13
Annual Mean Temperature	Climatic	53,5	0-5	BIO 1
Net Primary Production	Vegetation	53,1	0-5	NPP
Temperature Seasonality	Climatic	50,5	0-5	BIO 4
Annual Precipitation	Climatic	50	0-5	BIO 12
Multiresolution Index of Ridge Top Flatness	Relief	43,5	0-5	MRRTF
Min Temperature of Coldest Month	Climatic	41,2	0-5	BIO 6
Topographic Openness	Relief	36,6	0-5	TO
Sky View Factor	Relief	32,6	0-5	SV
Valley Depth	Relief	20,1	0-5	VD
Solar Diffuse	Relief	8,9	0-5	SD
Drainage Density	Relief	8,8	0-5	DD
Morphometric Protection Index	Relief	6,3	0-5	MPI
Max Temperature of Warmest Month	Climatic	5,4	0-5	BIO 5
Digital elevation Model	Relief	2,4	0-5	DEM
Effective Air Flow Heights	Relief	0	0-5	EAFH
Precipitation Seasonality	Climatic	100	5-15	BIO 15
Precipitation of Driest Month	Climatic	98,7	5-15	BIO 14
Ridge Level	Relief	76,7	5-15	RL
Precipitation of Wettest Month	Climatic	65,6	5-15	BIO 13
Annual Precipitation	Climatic	34,3	5-15	BIO 12
Temperature Seasonality	Climatic	32,8	5-15	BIO 4
Annual Mean Temperature	Climatic	29,2	5-15	BIO 1
Net Primary Production	Vegetation	28,9	5-15	NPP
Min Temperature of Coldest Month	Climatic	20,9	5-15	BIO 6
Multiresolution Index of Ridge Top Flatness	Relief	7,5	5-15	MRRTF
Topographic Openness	Relief	0	5-15	TO
Precipitation of Driest Month	Climatic	100	15-30	BIO 14
Precipitation Seasonality	Climatic	87,1	15-30	BIO 15
Precipitation of Wettest Month	Climatic	74	15-30	BIO 13
Ridge Level	Relief	57,7	15-30	RL
Annual Precipitation	Climatic	51,7	15-30	BIO 12
Temperature Seasonality	Climatic	44,5	15-30	BIO 4
Net Primary Production	Vegetation	41,3	15-30	NPP
Min Temperature of Coldest Month	Climatic	39,3	15-30	BIO 6
Annual Mean Temperature	Climatic	37,1	15-30	BIO 1
Topographic Openness	Relief	9,3	15-30	TO
Sky View Factor	Relief	8,4	15-30	SV
Drainage Density	Relief	6,3	15-30	DD

Predictor	Group	Importance (%)	Soil depth (cm)	Abbreviation
Solar Diffuse	Relief	1,6	15-30	SD
Effective Air Flow Heights	Relief	0,5	15-30	EAFH
Multiresolution Index of Ridge Top Flatness	Relief	0	15-30	MRRTF

Main

l. 34 The given reference (1) does not investigate warming at AP or MA. In addition, a more recent reference should be added here.

A: *We agree with the reviewer and have replaced the references as requested.*

l. 35 The given reference (2) suggests that Antarctica served as a C sink during the late Palaeocene/early Eocene.

A: *We agree with the reviewer and have replaced the references as requested.*

l. 37 What do you mean by "soil storage"? References (4) and (5) focus explicitly on MA and/or King George Island - this does not refer to Antarctica as a whole. l. 38 "SOCs"?

A: *Soil carbon storage is the process of capturing and holding carbon in the soil, helping to reduce atmospheric carbon dioxide and mitigate climate change. Since we have specified our study area as Maritime Antarctica and the Antarctic Peninsula throughout the text, we believe it is unnecessary to replace these two references.*

l. 41 "hazardous scenarios" does not sound appropriate

A: *We agree with the reviewer and have adjusted the text by replacing "hazardous scenarios" with "...projection scenarios..."*

l. 37-43 Please review this whole sentence and split it at least into two sentences.

A: *We agree with the reviewer and have adjusted the text following the reviewer's recommendations:*

"Despite the well-documented soil organic carbon (SOC) stocks in the Arctic terrestrial ecosystems, uncertainties persist regarding the precise SOCs. There is also uncertainty about the impact of climate change on SOC stocks dynamics [4]. Specifically, it is unclear whether Antarctic soils will serve as a carbon sink or source if the Intergovernmental Panel on Climate Change (IPCC) projections scenarios of the global average temperatures increasing 1.5°C to 2°C are reached in the medium to long-term [9,10,11]."

l. 43 Context with the given references (9), (10), and (11) is not clear. Do you want to show that there is no data about Antarctic soils? Please make this clear, especially for (11).

A: *We agree with the reviewer and have adjusted the text accordingly. After making these adjustments, we believe the references now make more sense. If there are still any issues or if further clarification is needed, please let us know, and we will make additional adjustments.*

l. 49 It is not clear why you added reference (6) here.

A: *We agree with the reviewer and have adjusted the references accordingly. We have updated the references to clarify that other researchers have encountered similar difficulties in working with and collecting soil samples in Antarctica for pedological studies and predictive modeling. The following references were added:*

"The Challenges of Doing Soils Research in Antarctica: A Day in the Life of Ed Gregorich" and "Modelling and prediction of major soil chemical properties with Random Forest: Machine learning as tool to understand soil-environment relationships in Antarctica".

l. 55 Why did you add reference (21) here? Where is the connection to active layer depths?

A: *We agree with the reviewer and have adjusted the text by removing the mentioned reference.*

l. 56 What is the connection between the references (13) and (22) and the prediction of SOC stocks over time and their correlation with climate change? Both studies have a completely different focus.

A: *We agree with the reviewer and have adjusted the text by removing the mentioned references and added a more concise and related reference: "Spatial heterogeneity and environmental predictors of permafrost region soil organic carbon stocks"*

l. 57-59 What is the "influence of the Antarctic cryosphere" on SOC stocks that you refer to here? Do you assume there are C stocks frozen in the permafrost like in the Arctic? Is it the melting of ice shields? What is the point here? The studies you named before didn't even have their focus on SOC stocks.

A: *We agree with the reviewer that this sentence was confusing and based on inappropriate references. We have revised the sentence and updated the reference according to the reviewer's feedback.*

"However, most of these studies were conducted in Arctic soil environments (Kåresdotter et al., 2021; Miner et al., 2022; Schuur et al., 2022), with fewer studies focusing on Antarctic soils in the context of global warming. This is primarily due to the limited availability of soil data and complexity of the Antarctic continent (Siqueira et al., 2023), as well as the insufficient representation of Antarctic soils in global soil databases(Siqueira et al., 2024)."

l. 61 I don`t think that "glaring omission" is a very appropriate term.

A: **A:** *We agree with the reviewer and have replaced the term "glaring omission" with "significant gap."*

l. 63-66 "Uncertainties, insufficient information, and challenges"? This is way too imprecise for a scientific paper. What regional and global consequences do you have in mind?

A: *We agree with the reviewer that this sentence was indeed imprecise and unclear. We have revised the sentence to make it more precise and clearer for future readers, in accordance with the reviewer's feedback.*

l. 66-69 0,35% of the Antarctic continent is so far ice-free (Bockheim&Haus 2014) and Antarctica comprises less than 10% of the global land surface. Do you think a lack of knowledge regarding this area "pose obstacles to global warming mitigation strategies... and... constrain the accuracy of the overall long-term predictions of current climate change models"? It is without doubt necessary to investigate soil organic matter, soil development, and changes driven by climate warming in Antarctica, but your framing is not appropriate.

A: *We agree with the reviewer and have made the necessary adjustments to the sentence.*

l. 70-77 You can not add here in the last sentence that the "primary areas of study focused on MA and the AP". First, ALL of your study focuses on MA and AP. Regarding the fact that MA and AP are very special regions with special conditions (see for instance Vaughan et al., 2003), you can not use them to draw conclusions on the whole continent.

A: *We agree with the reviewer and have no intention of making generalized conclusions for the entire continent. We have revised the objectives to clearly specify that our study areas, as well as our conclusions, pertain specifically to regions with distinct climatic conditions: Maritime and Peninsular Antarctica.*

"Here, our objective was to predict the dynamics of SOC stocks at various soil depths in the present time and under three different future climate change scenarios for the 0-30 cm soil layer. Additionally, we aimed to evaluate whether the soil in ice-free areas of MA and the AP, which have distinct climatic conditions, acts as a source or sink for atmospheric carbon. To achieve these goals, we utilized climate data from Chelsea under the IPCC global scenarios, incorporating topographic variables and, net primary

production, and employed machine learning techniques. Three Shared Socioeconomic Pathways (SSPs) were considered in the predictive model."

Results

l. 81 Again, this is not Antarctica - this is MA and the tip of the AP with James Ross Island

A: *We agree with the reviewer and adjust the sentence:*

"The predicted SOC stock maps illustrate variations in carbon stock, ranging from 0.56 to 19.27 Mg ha^{-1} across three soil depths and different islands that compose MA and AP, including James Ross Island (Fig. 1).

l. 81-83 What is your first analysis? The prediction of the SOC stock at the present time? I am not sure if you should call a prediction an analysis. And why should a prediction of the present time account for SSP scenarios in the future?

A: *We believe that the problem in this context was the English language and the use of inappropriate words. However, we have reviewed the sentence and adjusted it according to the issue pointed out by the reviewer, as following:*

"In the first SOC stock map (Fig.1), our predictive model currently demonstrates the SOC stock at the present time."

l. 84 It reflects the predicted conditions of the present scenario? What do you mean - the status quo?

A: *We agree with the reviewer that the sentence was not clear. We have reviewed and adjusted it to make it clearer and more fluid as follows:*

"Consequently, our values and the spatial distribution of SOC stocks exclusively reflect the predicted conditions of the present moment."

l. 93-104 It is obvious that if you have absolute values (Mg) the area has an impact. I don't understand why you explain this at length.

A: *This explanation was provided to facilitate understanding for those not in the field. The details were intended to contrast areas with large amounts of stored carbon based on their relative size with soils that store high concentrations of carbon in smaller areas.*

l. 127 "The quantities of SOC stocks stored or lost in the prediction our model..."?

A: *We agree with the reviewer that the sentence was not clear. We have reviewed and adjusted it to make it clearer and more fluid as follows:*

"The quantities of SOC stocks predicted by our model also varied according to the different islands mapped".

l. 130-134 With this in mind you think it is appropriate to give statements about the whole of Antarctica?

A: *We agree with the reviewer. In this section, we have specified the areas evaluated and clarified the conclusions that can be drawn. We have revised the entire text to avoid mistakes and overgeneralizations regarding all of Antarctica, as we did not assess the entire continent.*

Figure 3: It would increase the readability of the figure when you added information on the variables directly to the figure - or when you replaced the variables with meaningful abbreviations or terms.

A: *We use acronyms that are commonly found in the literature (Bedia et al., 2013; Romero et al., 2018) and are standardized by global climate model products (such as Chelsea and Worldclim) to make it easier for researchers to identify the variables used and to facilitate future citations of this work.*

l. 185-191 Did you at some point take into account that global warming will most probably increase ice-free areas?

A: *Indeed, we did not consider the increase in ice-free areas in our model, and we highlight this as a limitation in the discussion of this work, as described in the following excerpt:*

"Furthermore, our model does not account for the dynamics of glacier retreat, the volume and distribution of meltwater in response to increased precipitation, and the size of the ice-free areas."

Additionally, there is a gap in understanding how the melting of glaciers and expansion of ice-free areas in Antarctica will occur, as this process depends on changes in air masses which also need to be modelled. Addressing this would require a separate study.

l. 198 What is "active" periglacial erosion?

A: *Active periglacial erosion happens in cold areas where ice isn't present but the ground frequently freezes and thaws. This freeze-thaw cycle causes rocks to crack and break apart. As the broken pieces move downhill, they shape the land, creating features like sloping soil and unique surface patterns. Periglacial erosion is a significant geomorphic process in cold regions, shaping the landscape in the absence of glaciers. Processes occurring in periglacial environments, resulting from the active freezing and thawing of water in the porous spaces of the soil and areas with varying altimetric levels (slopes), generate secondary phenomena such as solifluction, which is a special type of erosion.*

We have added a short sentence explaining what this phenomenon is for researchers unfamiliar with this topic:

"In regions experiencing active periglacial erosion (freezing and thawing of water in soil pores and on slopes in cold environments, which cause specific types of erosion),..."

l. 197-206 What kind of audience do you want to address with this paper?

A: *We hope to reach scientists from a range of disciplines with this paper, including soil scientists, polar researchers, climatologists, pedometrists, ecologists, and environmental scientists, among others.*

l. 197-211 Here are several references missing.

A: *We appreciate the reviewer's feedback and have added references where we found them to be relevant. If the reviewer believes that additional references are necessary or that any of the current ones should be replaced, we are open to further suggestions and would be happy to improve the sentence accordingly.*

l. 212 If you are convinced that the reference (18) is needed, you should put it into context and not just write it down at the end of the paragraph.

A: *We agree with the reviewer and complement the sentence in order to be more precise and contextualize it.*

l. 213-220 Vegetation/NPP is a difficult variable in this area. First, you cannot just expect that vegetation is there and plant litter contributes to the SOM/SOC. So far, vascular plants are only present on some islands in the region of MA and AP. That means, the proliferation of plant seeds etc. has to be taken into account - this is a huge difference compared to other regions. If this is not possible in your model, you have to address it. Second, you should be familiar with the greening/browning phenomenon also known from the Arctic. So far, it is not clear if vegetation reacts with expansion (and greening) to warming or if the increasing evaporation leads to dieback of the highly adapted organisms (browning). Please check for instance Robinson et al., 2018 and Amesbury et al., 2017.

A: *Incorporating data on plant propagule proliferation into our predictive models of SOC stock would be challenging, as such data is not available for future scenarios, nor is there representative data on the current dispersion of these propagules across the entire study area. Consequently, we acknowledge this as another limitation of our models. We thank the reviewer for pointing out these limitations. We have addressed these issues by including a detailed sentence in the limitations section of our manuscript, discussing these limitations and highlighting them as suggested. Additionally, we have incorporated the references provided by the reviewer to support this discussion as following:*

"Plant biomass inputs in surface soils play a crucial role in changes to SOC stock. The retreating glaciers expose new areas for plant colonization, while warmer temperatures

enhance the plants' growth(Tang and Baldocchi, 2005). This expansion leads to rapid soil development, with increased vegetation cover correlating with higher levels of SOC, nitrogen, and organic matter in the soil(Strauss et al., 2009). The expansion of plant communities can further enhance NPP and, consequently, influence SOC stocks. However, it is important to note that the areas currently colonized by vascular plants in MA and AP are limited to a few locations(Komárková et al., 1985). For new areas in MA and AP to be colonized in response to increases in temperature and nutrient availability, and for subsequent contributions to SOC transport and stock, it is essential for plant propagules to reach these new areas. This represents a limitation of our models, as we were unable to incorporate data on plant propagules or trends in vegetative propagation for future scenarios. Furthermore, a simple increase in NPP does not necessarily mean that new ice-free areas will be colonized by plant communities and, as a result, see increases in SOC stocks. Temperature increases could lead to extreme climate conditions as colder and harsher winters, potentially resulting in reduced snowmelt and increased aridity in some areas(Robinson et al., 2018). This could restrict plant colonization and result in either greening or browning of the landscape. Therefore, it remains unclear whether vegetation in MA and AP will expand (and greening) in response to warming or if increased evaporation will cause dieback of highly adapted organisms (browning)(Amesbury et al., 2017; Robinson et al., 2018). Additionally, it was not possible to include these factors as predictor variables in our models for SOC stock."

Figure 4: What is the point of the thresholds here? Where do they derive from? What is the reason for the scale of annual precipitation? Where is the "Antarctic limit" in the map? Where do the colors of the scales reflect on the map? This whole figure needs to be revised and to be made clear. "The gradients of these three variables decrease from left to right"? If annual precipitation decreases from left to right, something is wrong with your scale.

A: *Thank you for your detailed feedback. We have revised Figure 4 as per the suggestions of another reviewer, and we believe these changes also address the concerns you've raised. The entire figure has been updated for better clarity. The thresholds in Figure 4 were now stablished in all areas evaluated. The 'Antarctic regions (AP and MA) limit' is now clearly indicated on the map in. We have added a label for clarity. The scale for annual precipitation was chosen to represent the amount of precipitation of different*

regions trying to show a climatic gradient, ensuring that the data is represented accurately across different regions. We have revised the color scale to ensure that it accurately reflects the corresponding data on the map. The statement regarding the gradients has been revised for accuracy. We have ensured that the annual precipitation scale is consistent with the direction of the gradients.

In addition to the modifications requested by the two reviewers, we addressed the two issues they pointed out (which effectively contributed to improving the work) and created three additional figures that illustrate the climatic and NPP gradients between the islands in detail. These figures have been added to the "extended data" section, with appropriate references to them in the text, so that future readers can access the detailed information.

""Consequently, temperature and precipitation exhibit a declining climatic gradient from north to south, which also aligns with a decrease in the NPP gradient (Figures 5, 6 and 7, extended data). However, the MA shows a more homogeneous pattern of precipitation and temperature due to the islands being relatively aligned longitudinally, which results in consistent patterns of NPP. (Figures 5, 6 and 7, extended data)."

l. 260-261 "Our results suggest a relationship between SOC stock values and increases in NPP"? This is a finding of your work?

A: *The reviewer is correct. Our models demonstrated this relationship for our Antarctic Peninsula (AP) and Antarctic Maritime (AM) study areas, as shown in Figure 5e.*

l. 315-319 Please revise this sentence. Your reference (21) dates back to 2010 - don't you think that additional work has been done in the last 15 years? References (22) and (23) are unnecessary self-citations.

A: *We agree with the reviewer and have replaced the reference with a more current one from 2024. In addition, we have removed the self-citation references as requested by the reviewer.*

Discussion

l. 346 You have no information on soils in most parts of Antarctica in your study.

A: *We actually agree with the reviewer and have adjusted the sentence to avoid misinterpretation.*

l. 353-379 Where does this comparison with the Arctic come from? How can you compare both regions, especially "certain regions of Antarctica" with "some regions of the Arctic"?

A: *Dear Reviewer, at this point, we would like to make a general comparison between our studied regions in Maritime and Peninsular Antarctica and some areas of the Arctic. This comparison is intended to highlight how the carbon feedback trends in these regions tend to behave oppositely in response to climate change, supported by relevant literature. We believe this comparison adds valuable context and depth to our study, while remaining aligned with our research objectives. Certainly, further research specifically aimed at comparing phenomena between the two Earth cryospheres using tailored methods is essential. This is actually the next step for our group, as we are now expanding our work to the Arctic while continuing our research in Antarctica through international collaborations.*

In response to the reviewer's concerns, we have made slight adjustments to the sentence to clarify the comparison and ensure it aligns with recent literature:

"Our findings suggest that atmospheric carbon feedback dynamics in certain regions of MA and AP exhibit a trend to negative feedback, which contrasts with the positive atmospheric carbon feedback trend observed in the some regions of the Arctic(Miner et al., 2022; Natali et al., 2019). *While some regions of the Arctic tends to function as a carbon source throughout permafrost melting*(Miner et al., 2022; Natali et al., 2019; Schuur et al., 2024)*, exhibiting positive feedback, MA and AP regions tends to act as a sinkhole, exhibiting negative feedback."*

However, if the reviewer feels it is necessary to remove or modify this sentence, please let us know. We are open to any suggestions for improvements.

l. 375-379 This is only true if you do not have processes like cryoturbation etc. And I do not see why this should be relevant to your work.

A: *Dear Reviewer, we agree with your observation. At this point, we aimed to provide a plausible explanation for the phenomenon observed in our analyses. In doing so, we used the phrase "may be" and supported our explanation with relevant literature. However, we have carefully considered your feedback and have added a clarifying sentence at the end of the paragraph. If you still believe it is necessary, we are open to removing or modifying the sentence in a second round of revisions.*

l. 384-385 Colonization/expansion of plant communities is restricted to the proliferation of plant seeds etc. - this might be true for MA and AP where vascular plants are present, but not for other parts of Antarctica. Accordingly, reference (32) investigates soils on Stepping Stones on the west coast of the AP.

A: *We agree with the reviewer and have revised the sentence to clearly specify the study area. Additionally, we have replaced the outdated reference with a more relevant one, where researchers worked in a similar area to ours.*

l. 392 Reference (33) investigates C uptake by lichens and bryophytes - lichens are no plants.

A: *We acknowledge the reviewer's observation and recognize that an error was made. Consequently, we have revised the reference in accordance with the issue highlighted by the reviewer.*

l. 392 Reference (34) - focusing on MA - concludes "A net loss of CO2 that was observed in the sites predominantly colonized by higher plants and without vegetation cover occurred due to higher mineralization processes associated with elevated soil temperature and absence of vegetation cover, respectively." I do not see the connection with your statement.

A: *We agree with the reviewer's feedback, made a minor revision to the sentence, and removed the cited reference.*

l. 394 Reference (5) investigates CO2 emissions, not SOC stocks.

A: *We agree with the reviewer's feedback, made a minor revision to the sentence, and removed the cited reference.*

l. 400 Do you think the authors of reference (41) were the first to investigate this relation? Please cite basic literature and avoid unjustified self-citations.

A: *We agree with the reviewer's comments and have made a minor adjustment to the sentence, as well as added a new reference alongside the previous one. Dear Reviewer, we would like to highlight that our group is among the most active contributors to Antarctic soil science and its interactions with other environmental spheres. Additionally, we collaborate with experts from various scientific disciplines. As a result, it is natural that our work may be self-cited from time to time, depending on the context.*

l. 402-409 As you exclusively study soils in MA and AP this whole part is not needed.

A: *We agree with the reviewer and have removed the entire sentence as requested.*

l. 409-412 Again, this is not true for Antarctic soils in general. And obviously, it does not play a role in your model?

A: *We agree with the reviewer. We have reviewed and adjusted this entire sentence to avoid misconceptions:*

Furthermore, notable contributions to SOC levels/stocks in penguin rookeries Antarctic soils come from the substantial input of guano excrement by penguin rookeries and sea-birds in terrestrial environments, establishing them as the dominant factors influencing SOC dynamics. Although SOC levels in these areas are high, these areas are relatively small and unrepresentative at the Antarctic scale.

l. 412-417 Where is the connection to your work? You repeat that soil depth plays a role regarding SOC stocks.

A: *Our models evaluated SOC stocks at different depths. However, the explanations provided in this part of the discussion, concerning the soil-landscape relationship, were based on pedological knowledge of the area and supported by the literature. If the reviewer still considers it necessary, we can remove this sentence. Please let us know.*

l. 422-423 First, where is the connection to central Spain here? Second, are you convinced the authors of reference (45) were the first to investigate this connection?

A: *We agree with the reviewer that it was a mistake to compare different environments. Therefore, we have removed the sentence and the quoted text.*

Conclusion

l. 435-436 This sentence perfectly outlines your work. If you write the whole manuscript according to it, it could work.

A: *We agree with the reviewer and have adjusted the entire text to clarify that our study area, results, and conclusions pertain specifically to MA and AP.*

l. 450 Where do the "carbon-emitting areas in the Arctic" come from? What is the scientific reasoning behind this trade-off?

A: *The key environmental variables crucial in predicting SOC stocks included those associated with net primary production, temperature, and precipitation. In tandem with soil attributes, such as effective soil depth, texture, soil bulk density, and relief, these factors collectively influence the dynamics of SOC stocks. Ice-free areas that naturally exhibit lower SOC stock values are typically predicted to see an increase in SOC stocks (the majority of areas), whereas those with higher values are predicted to see a decrease in SOC stocks. However, the impact of this carbon storage on mitigating global warming and counterbalancing carbon-emitting areas in the Arctic permafrost thaw remains uncertain and requires further robust studies for clarification. This is due to the fact that carbon emissions from the Arctic primarily come from thawing (Miner et al., 2022;*

Schuur et al., 2024, 2015), which releases large amounts of stored carbon. In this context, MA and AP is a potential carbon sink, while the Arctic is a potential carbon source.

Methods

l. 455 Why "primary"?

A: *This word was deleted to avoid confusion for future readers and to make the text clearer.*

l. 506 Is (64) the first time this method was described?

A: *The reference was replaced and an international literature with the method was added.*

l. 510 "High stoniness"? Were the samples not sieved by 2mm before like it is usually done?

A: *Yes, the samples were sieved. Since Antarctic soils are sandy or silty due to incipient pedogenic activity and many of them are skeletal, sieving and the use of the aforementioned method are necessary. In this sentence, we provided a general description of the soil texture.*

Reviewer #3 (Remarks to the Author):

Authors conducted a study across Antarctica using legacy data of soil observations, data of environmental factors and modeled climate scenario data with machine learning. Authors report that under future emission scenarios Antarctica will be a sink of atmospheric carbon. Though authors did a praiseworthy job in attempting to answer an important question, but I see several limitations in the current format of the manuscript.

The Abstract must mention how many soils profile sites authors used, which environmental factors data were used, and what was the predictive accuracy of the baseline SOC stocks of ML models in the form of R^2 values.

A: *We agree with the reviewer and have added all the requested information to the abstract.*

Dear reviewer, at this point, we would like to highlight that we used mean absolute error (MAE), root mean squared error (RMSE), and Lin's concordance correlation coefficient (ρc) instead of R^2 as metrics to evaluate the performance of the models, as shown in Figure 5.

Are the number of samples (n=2800) represent observation sites or total number of analyzed samples, please clarify. Also, provide write-up of how these samples/sites represent the environmental variability of your study area?

A: *2,800 is an approximation of the total number of samples, not necessarily the number of locations. For each soil depth, the number of locations varied as follows: 0-5 cm = 915 locations; 5-15 cm = 936 locations; 15-30 cm = 746 locations. Among the different depths, there were instances where the coordinates converged, meaning the samples from the 0-5 cm, 5-15 cm, and 15-30 cm layers were collected at the same point. However, there were also divergences, where the samples from one or more depths were collected at different locations, resulting in distinct coordinates between layers.*

The representativeness of the different pedo-environments was ensured by using observation sites across various soil types, lithologies, topographic positions in the landscape, and climatic gradients in paraglacial, periglacial and proglacial environments.

At the reviewer's request, we have inserted this observation in a relevant part of a new paragraph of the discussion, in the part where we have added the three references requested by the reviewer.

"...However, we ensured environmental variability by collecting samples from different pedoenvironments, landscape positions, various lithologies, and distinct climatic conditions in paraglacial, periglacial and proglacial environments."

Reported R^2 values (~0.29) are very poor and may not merit publication unless authors do a better job of employing a large number of environmental factors to increase the predictive accuracy of the used ML models. Also, I am surprised to see that authors did not use any studies which have attempted to answer the same question using similar methodologies in different parts of the world, for example:

Gautam, et al. 2022. Climate change may release over 1.8 petagrams of soil organic carbon from topsoils in the United States by 2100, Global Ecology & Biogeography, 31, 1146-1160, doi: 10.1111/geb.13489.

Wang, et al. 2022. Global soil profiles indicate depth-dependent soil carbon losses under a warmer climate, Nature Communications, 13, 5514, doi:10.1038/s41467-022-33278-w.

Wang et al. 2024. Responses of soil organic carbon to climate extremes under warming across global biomes, Nature Climate Change, 14, 98–105, doi:10.1038/s41558-023-01874-3.

I want authors to cite and discuss these previous findings as it relates or differs with their findings.

A: *Dear Reviewer, thank you for highlighting this issue. We would like to clarify that R^2 was not used in our analysis, and therefore, it is not referenced in the tables, figures, or text of the manuscript. Furthermore, we would like to highlight that we used Lin's Concordance Correlation Coefficient (ρc) instead of R^2, and our results were satisfactory for the type of modeling conducted.*

Lin's Concordance Correlation Coefficient (ρc) was chosen instead of R^2 due to its ability to assess both the precision and accuracy of predictions. It is particularly sensitive to systematic deviations from the line of identity (1:1), making it more suitable for evaluating the agreement between observed and predicted values in our study context. The ρc is particularly important when we are interested not only in assessing the general trend between observed and predicted values but also in accurately evaluating how close the predicted values are to the observed values. This distinction is crucial in studies where predictive accuracy is more relevant than merely explaining variance. For example, when predicting carbon stock values of 100, 200, and 300 Mg ha^{-1} in regions where observed values are only 1, 2, and 3 Mg ha^{-1}, the coefficient of determination R^2 might suggest an

excellent fit with values close to 1. However, this would mask a substantial error in predictions, which would be far from the observed values. In such scenarios, relying solely on R^2 can lead to misleading conclusions about the model's effectiveness. On the other hand, ρc corrects this bias by considering both the precision and accuracy of the predictions. It penalizes predictions that, although they might follow the correct trend, are distant from the observed values. This results in a metric that better represents the model's true capacity to generalize. This consideration is especially important in studies where predicted data will be used for practical inferences, such as our study conducted in Antarctica. In these cases, it is essential to ensure that predictions not only follow the correct trend but also closely match the actual values, especially when these predictions will inform critical decisions about climate change mitigation. Thus, by opting for ρc instead of R^2, we ensure that our conclusions are based on a more robust and accurate assessment of the model's performance. This approach also allows for a more cautious interpretation of results, taking into account possible limitations of the data used, such as intrinsic variability of soil profiles, environmental factors, and climate projections.

Dear Reviewer, we appreciate you providing us with very important and recent references in the area, published in excellent journals. We would like to point out that we had already cited two of the three references you mentioned (Wang et al., 2022 and Wang et al., 2024), which were listed as references 9 and 10 in the first version of our manuscript. In addition, we thank the reviewer for this important contribution, which we believe has significantly enriched the discussion of our work. We have incorporated a more in-depth analysis, considering the works mentioned by the reviewer, and have inserted an entire paragraph to address the points raised in this section as following:

"Our results indicated that for soils in ice-free areas of MA and AP, the main environmental factors controlling the variability of SOC stock under different climate change scenarios are temperature, precipitation, and net primary production. This is consistent with the findings of Gautam (2022)(Gautam et al., 2022), *who assessed the vulnerability of soils in the Continental United States to climate-induced SOC loss by 2100. Furthermore, as noted by Gautam (2022), soil attributes such as soil type and its characteristics also play a role in determining SOC stock. Although we included key attributes related to SOC stock, such as soil bulk density and depth, detailed data on soil types (Orders) were not specifically used in our models. This was a limitation, as soil type information was not available for all samples analysed. However, we ensured*

environmental variability by collecting samples from different pedoenvironments, landscape positions, various lithologies, and distinct climatic conditions. Important and innovative studies conducted by Wang (2022) and Wang (2023)(Wang et al., 2023, 2022) *demonstrated that global soils tend to be a source of carbon to the atmosphere under global warming scenarios (positive carbon feedbacks). However, our results revealed that, in most areas of MA and AP, soils are likely to act as a CO_2 sink under global warming scenarios. It is important to highlight that, in MA and AP, some islands may act as CO_2 sources, while a few others may show neutral SOC responses under different climate change scenarios, following the same tendencies demonstrated by Wang (2023)*(Wang et al., 2023) *which revealed distinct (positive, neutral, or negative) SOC responses in global soils under global warming. Our findings also align with the authors' conclusions that the largest sinks tend to occur in cold-desert environments with minimal vegetation, and that the most significant SOC sink effects in MA and AP soils are likely to occur in the most superficial soil layers, as observed by Wang (2022)*(Wang et al., 2022)*."*

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REBUTTAL LETTER

Dear reviewers, we sincerely thank you once again for your valuable contributions, which have undoubtedly enhanced the quality of our work and increased its chances of publication in this esteemed journal. All revisions have been addressed in this response letter, and the necessary changes to the manuscript have been highlighted in the track changes version, as requested.

REVIEWER COMMENTS:

Reviewer #1 (Remarks to the Author):

The authors have accepted almost all the suggestions and corrections. With the changes introduced, I believe the focus of the work has improved significantly. Both the additional information in the introduction and in the discussion greatly enrich the work. I want to congratulate the authors on the work done. Although they did not include a white polygon on Deception Island, I understand that the map's scale is very general and that it might appear too small. However, I personally think it would be worth the effort. My cartographic training makes me continue to interpret this omission as an error, but I accept the authors' arguments.

A: *Dear Reviewer, thank you for your understanding. Our geoprocessing team has been carefully considering the best approach to represent the maps as clearly and effectively as possible.*

I would like to comment on a few things:

- # Line 83-84: "Even for the most advanced and recent studies modelling SOC stocks, Antarctic ice-free areas remain a significant gap…" I disagree with this statement; there is some recent work that models the distribution of SOC in the Byers Peninsula that could be cited. It's just a suggestion since I am the author of that work, so I don't feel it's appropriate to insist on citing it, but I would like them to do so.

Fernandez, S.d.C., Muñiz, R., Peón, J., Rodríıguez-Cielos, R., Ruız, J., Calleja, J.F., (2024) Mapping dissolved organic carbon and organic iron by comparing deep learning and linear regression techniques using sentinel-2 and worldview-2 imagery (byers

peninsula, maritime antarctica). Remote Sensing 16. URL: https://www.mdpi.com/2072-4292/16/7/1192, doi:10.3390/rs16071192.

A: *We have accepted the reviewer's suggestion, made a slight adjustment to the sentence, and cited the recommended work.*

- # New Title: “Global warming turns ice-free areas of Maritime and Peninsular Antarctica into soil organic carbon sinks”

I disagree with the new title. Although it’s true that the model was developed using samples from those areas (Maritime and Peninsular Antarctica), I believe that the model and its predictions are valid for the entire Antarctic region. I preferred the original title, although I understand that the change was made to address another reviewer’s corrections. However, the model is indeed valid for any other ice-free location in Antarctica... and it’s a shame that the title cannot reflect that global predictive nature. Below, I suggest some alternative titles, one of which attempts to reflect the model’s uncertainty... which is not insignificant

- Predicting Soil Carbon Sequestration in Ice-Free Regions of Maritime and Peninsular Antarctica Under Intensified Climate Change Scenarios.

- Predicting Soil Carbon Storage in Ice-Free Regions of Antarctica Under Climate Change

- Global warming may turn ice-free areas of Maritime and Peninsular Antarctica into potential soil organic carbon sinks

A: *We agree with the reviewer and appreciate the excellent suggestions. We have decided to change the title to option 3: 'Global warming may turn ice-free areas of Maritime and Peninsular Antarctica into potential soil organic carbon sinks.*

Reviewer #2 (Remarks to the Author):

This is the revised version of the authors' study. They use a modelling approach to evaluate the effect of global warming on SOC stocks in Maritime Antarctica under different climate change scenarios. The authors made some effort to react to the reviewers' comments and the manuscript somehow improved. However, there are still some

concerns regarding the quality of the manuscript: Regarding the given references - I already commented on many references that did not fit the given statements in my first review. Now again, several references are already in the first paragraphs that do not fit. I stopped commenting on references from line 52 on. To achieve a manuscript that can be published, the authors should thoroughly check all the references they use and take care that they are appropriate. This is an integral part of scientific work. Regarding self-citations, there is no restriction for citing your work, but you should be careful and the references should fit very well - self-citations in the wrong context leave a bad impression and can negatively impact the reception of your work. I understand that you want to highlight that your group is "among the most active contributors to Antarctic soil science", but this can primarily be achieved by sound scientific work. In addition, your list of references should be checked in detail - some are given with all co-authors, some only with the main author et al. You have a limit of 50 references but give 97 references. A major concern is the Discussion - in most parts, the authors do not discuss their results, but focus on other researchers' work and bring up completely new topics. The Discussion needs to be completely revised. Another major concern is that several parts of the manuscript are still too wordy and contain redundant information and parts of the manuscript still need to be more precise. The Results section should be structured more clearly, parts of it are redundant and should be tightened.

A: *Dear Reviewer, we appreciate your insightful comments regarding the importance of citations and references in scientific papers. We fully agree that they are crucial elements of our manuscript that require careful attention.*

In response to your concerns about inaccuracies in the citations, we conducted a thorough review of all references. We have replaced some, relocated others, and excluded those that were deemed unnecessary. However, we would like to highlight that, in certain instances, we utilized secondary sources of citations published in reputable journals within the field. These secondary sources may not always fully capture the original study's scope or accuracy.

Should you identify any remaining inaccuracies in the references, please do not hesitate to inform us. We are committed to addressing any issues and would greatly appreciate your guidance in suggesting suitable citations.

Regarding the total number of references, we understand that the journal's maximum standard is 50. However, we have noted that several articles published in the same journal exceed this limit. We believe that all the citations included in our manuscript are necessary. Nonetheless, if there is a requirement to reduce the number of references to comply with the journal's standards, we kindly request your assistance in determining which references could be excluded.

In the results and discussion section, we have carefully revised the text in accordance with all the reviewer's recommendations. We aimed to enhance clarity by removing redundant sentences and providing more detailed explanations, along with adjusting the references to better support our discussion.

Thank you for your understanding and support.

Sincerely,

Please see my detailed comments below (line numbers refer to the revised manuscript without changes marked):

Title

The new title fits the scope of your work much better. However, as your predictions are based on modeling, I suggest attenuating it slightly by adding "most probably" or "Global warming has the potential to..." or something similar.

A: *We agree with the reviewer and thank them for the excellent suggestions. We have chosen to change the title, as recommended by Reviewer 1, which also addresses the concern raised by Reviewer 2: 'Global warming may turn ice-free areas of Maritime and Peninsular Antarctica into potential soil organic carbon sinks.*

Abstract

l. 21 I suggest to use "stocks" (plural) here.

A: *We adjusted the sentence as suggested by the reviewer.*

l. 29 Do you mean the Chelsa database?

A: *Yes. We adjusted the sentence.*

l. 34 I suggest adding future tense here, for instance "...are going to increase..."

A: *We adjusted the sentence as suggested by the reviewer.*

l. 36 Same here, I suggest emphasizing the future aspect more.

A: *We adjusted the sentence as suggested by the reviewer.*

l. 36/37 I suggest replacing "intensity of the soil carbon sink" with a better fitting term - if I get it right, you are interested in how much the C sinks increase.

A: *We adjusted the sentence as suggested by the reviewer.*

Main

l. 41/42 "The Island of Maritime Antarctica..." is not correct. Should be "The islands of Maritime Antarctica..." Do you mean the Eastern AP or the islands east of the AP?

A: *We adjusted the sentence as suggested by the reviewer. Here we referred to Eastern AP.*

l. 43 Please be precise. Adams et al. state that the AP showed rates of warming that are "some of the fastest measured in the Southern Hemisphere". Same with Vaughan et al. - they identified three regions of recent rapid regional warning, with the AP being one of them. That does not mean that the AP "is experiencing the most rapid warming... in the world". In addition, I suggest to refer to original references (in case of Adams et al.) and to references that are more recent.

A: *We agree with the reviewer and have made an effort to be more precise with the citations, as suggested. In addition, we have used the original reference (Adams et al.) as suggested by the reviewer. We have noted that several works published within the Nature group itself cite the referenced studies. Therefore, we do not believe it is necessary to add*

additional references for this specific sentence, especially since our manuscript has already exceeded the maximum number of references allowed.

l. 43/44 Again, the reference (Gray et al.) does not fit here. The authors investigated the role of green snow algae and their carbon sink in the AP region - there is no connection with the whole of Antarctica becoming a C sink.

A: *We adjusted the sentence to precisely specify the region of Antarctica studied by the cited author, addressing the issue raised by the reviewer.*

l. 45-47 What is your statement here? What is the relation to Arctic ecosystems? Already in my first review, I wondered what you mean by SOCs - and did not receive an answer. The s implies a plural that does not make sense - soil organic carbons? Please revise this sentence.

A: *Dear Reviewer, we apologize for the lack of explanation in the first round of reviews.*

1 - In the sentence in question, our intention was only to highlight those studies on soil organic carbon stocks (SOC stocks) in the Arctic are more extensively documented compared to those in Antarctica, for comparison purposes. We acknowledge that the comparison with Antarctica was not clearly specified, and we have corrected this in the revised version.

2 - The use of "SOCs" was indeed a typographical error that went unnoticed during the initial review. We have corrected it in response to the issue you pointed out. Thank you for your understanding.

l. 51 Smith et al investigate the glacial organic C pool in the McMurdo Dry Valleys and Benavent-Gonzalez et al. the interplay between vegetation and soil functioning. From this point on I stop commenting on your references. I expect you to thoroughly check all your references and revise your manuscript accordingly to achieve a manuscript that is fit for publication.

A: *Both the sentence and the references have been adjusted or deleted as necessary. From this point forward, as noted by the reviewer, all references have been thoroughly checked.*

If the reviewer identifies any additional references that should be adjusted or citations that need replacement, please let us know.

l. 52 Where is the connection between your work and East Antarctic soils?

A: *To align this sentence with the cited references and our work, we decided it would be best to refer to Antarctica in general.*

l. 55 What do you mean by "limited in number"? Number of species? Number of individuals?

A: *The sentence has been adjusted to clarify it for potential readers.*

l. 56-58 Carbon also accumulates elsewhere under warm conditions, please revise this sentence.

A: *Dear Reviewer, while we acknowledge that carbon can accumulate in high-temperature environments, such as tropical regions, in this section we are specifically addressing Antarctica environment, where we believe low temperatures are the main factor limiting the decomposition activity of soil microorganisms.*

l. 59 Do you count bird droppings as marine source of organic material? Please be precise.

A: *The sentence has been adjusted to clarify it for potential readers.*

l. 60-62 What about non-native vascular plants?

A: *We have revised the sentence to also highlight the importance of non-vascular plants in SOC accumulation in specific regions of Antarctica: "Non-vascular plants, such as moss cover, can drive the accumulation of SOC in soils in particular Antarctic areas, such as Victoria Land [12]".*

l. 68 It should be "...data from the harsh and..."

A: *The sentence was adjusted following the reviewer's recommendations.*

l. 67-71 Please rephrase this sentence.

A: *The sentence was rephrased following the reviewer's recommendations:*

"This is primarily due to the challenges of obtaining spatiotemporal data from the harsh and inaccessible ice-free areas of the continent, the high cost and time demands of fieldwork, the significant spatial heterogeneity of Antarctic environments, and the reduced soil carbon responses to climate variation caused by pedological processes[15,16]*."*

l. 86-87 "...the potential of current ice-free areas... to increase carbon stocks"? This sounds strange. Please rephrase and re-check the whole sentence.

A: *The sentence was rephrased following the reviewer's recommendations: "Moreover, the potential for current ice-free areas in Antarctica to increase SOC stocks in future climate change scenarios remains uncertain*[4]*"*

l. 89-91 I do not see why this is relevant here.

A: *We agree with the reviewer and removed this sentence.*

l. 100 Again, do you mean the Chelsa database? If not, please explain what you mean by Chelsea.

A: *Yes, here we referred to Chelsa database. The word was adjusted to Chelsa.*

Results

l. 107 "compose MA and AP"? The AP is not composed of islands and as your work does not cover all islands in the region I suggest rephrasing this sentence accordingly, for instance "...different islands in the region of MA and AP". In addition, it would be good to give precise information on "different islands" - how many?

A: *We agree with the reviewer and have adjusted the sentence exactly as suggested.*

l. 108-111 Please rephrase and shorten: "...currently... at the present time" and "...of the present moment" is redundant.

A: *We reviewed and adjusted the sentence following the reviewer's recommendations.*

l. 120-130 This passage is way too wordy, please shorten it. You can address the impact of the area in one sentence.

A: *We reviewed and adjusted the sentence following the reviewer's recommendations.*

l. 139-152 I suggest using increase (singular) instead of increases throughout the manuscript. In addition, I suggest using different words to enhance readability - this passage alone contains seven times the words increase and increases.

A: *We followed the reviewer's recommendations and used 'increase' instead of 'increases' throughout the manuscript.*

l. 139/140 I suggest rephrasing this sentence: "Our model predicts a substantial increase of SOC stocks for all three SSP scenarios." or something similar.

A: *We reviewed and adjusted the sentence following the reviewer's recommendations.*

l. 140-148 You can shorten this part. How can SOC increments have a direct proportional relationship with temperature increments when you have a decrease in SOC stocks in some islands? You should name that you first look at the whole region and afterward at the single islands.

A: *Dear Reviewer, we appreciate your suggestion and have made every effort to clarify the sentence in line with your recommendations. We have added the following excerpt:*

"While the SOC increments exhibit a directly proportional relationship with temperature increases across the entire region according to the SSP scenarios, some islands show a decrease in SOC stocks. Initially, we analyzed the overall regional trends, followed by a closer examination of individual islands (Fig. 2). Under SSP1-2.6 (1.5 °C warming), SOC stocks increase by 27.67% compared to present levels. In SSP3-7.0 and SSP5-8.5 (2.5 °C and 4 °C warming), SOC stocks increase more substantially by 53.34% and 52.89%, respectively (see quantile 0.5, Fig. 2, extended data). This corresponds to increases in

SOC stocks at 0–30 cm soil depth ranging from 17.22 to 51.07 Mg ha^{-1} in SSP1-2.6, 24.58 to 61.48 Mg ha^{-1} in SSP3-7.0, and 23.54 to 59.57 Mg ha^{-1} in SSP5-8.5."

l. 154/156 "are predicted to increase/decrease their SOC stocks" sounds like the islands are acting willfully. Please rephrase.

A: *We reviewed and adjusted the sentence following the reviewer's recommendations.*

l. 169 "considering all the SSPs global warming scenarios"? Are you considering all scenarios here now or the three you named before? Please be precise.

A: *Here, we refer to the three SSP scenarios mentioned earlier. We have reviewed and adjusted the sentence to enhance clarity and precision.*

l. 204-211 Please rephrase this passage and clarify it - at the moment it is rather confusing.

A: *We reviewed and adjusted the sentence following the reviewer's recommendations.*

l. 211-217 Too wordy.

A: *We reviewed and adjusted the sentence according to the reviewer's recommendations to make it more concise.*

l. 220 Why "elevation or height"? One term is enough.

A: *We reviewed and adjusted the sentence following the reviewer's recommendations.*

l. 218-222 Too wordy. Suggestion: "The variable ridge level (RL), which refers to the elevation of a ridge, explains 100% of the predicted SOC stocks within the surface layer. High RL indicates a proneness to erosion which significantly influences..."

A: *We reviewed and adjusted the sentence following the reviewer's recommendations.*

l. 222 "especially in periglacial-semiarid pedogeomorphic systems"? Is there a substantially different effect of erosion compared to other systems?

A: *Periglacial erosion in Maritime and Peninsular Antarctica is driven not only by freeze-thaw cycles and annual summer meltwater but also by strong winds that cause intense surface ablation. These winds, typical of this latitudinal zone, contribute significantly to shaping the landscape and increasing soil loss. Additionally, the high winds severely limit the taller growth of plants in the region, potentially affecting the area's carbon sink capacity.*

l. 224 Already in my first review I asked what you mean by "active" periglacial erosion - you explained periglacial erosion and added the respective information, but you did not answer my question. Is there a passive periglacial erosion? In other words: do you need the word "active" here?

A: *In this case, we mentioned periglacial erosion, which is active in summer (due to the melting of the active layer) and inactive in winter. However, we agree with the reviewer that the term is unnecessary and have removed it from the text.*

l. 230 I intended to stop commenting on references, but why did you reference the work of Walker et al. about calcium-rich Arctic (!) steppe here? In addition, information on colluvial soils has been available for much longer than 2001.

A: *Dear Reviewer, we are currently seeking a reference to support the assertion regarding greater terrain stability, increased likelihood of plant species colonization, and consequently, a higher contribution of soil organic carbon in the Antarctic environment. However, we have not found any studies in Antarctica that specifically demonstrate this relationship. Therefore, we cited a study from a similar environment with comparable climate, terrain, landscape dynamics, and vegetation size. To improve accuracy, we sought a more relevant work by the same author ("Terrain, vegetation and landscape evolution of the R4D research site, Brooks Range Foothills, Alaska"). If the reviewer is aware of any specific studies from Antarctica that demonstrate this relationship, we would greatly appreciate your guidance.*

l. 235 Reference (31) is not needed.

A: *The reference has been removed as requested by the reviewer.*

l. 236 What does "these areas" refer to? The flat terrains? This is confusing as you go back to RL in line 238.

A: *We agree with the reviewer that it was unclear which area we were referring to. Therefore, we have revised the sentence to clearly specify the area in question.*

l. 237 "hinder the presence of vegetation"? Rather "hinder the establishment of vegetation" or something similar.

A: *We adjusted the sentence exactly as the reviewer suggested.*

l. 238-241 I don't think that this part is relevant, but if you want to keep it you should shorten it and put it at the beginning of the RL passage.

A: *After re-evaluating based on the reviewer's comment, we agree that the sentence is unnecessary and have removed it as suggested.*

l. 244-246 This is trivial and you should not name it as one of your findings.

A: *We agree with the reviewer and have removed the sentence as suggested.*

l. 248 Did you include the proliferation of ice-free areas in your model?

A: *We did not include glacier retreat data in our models, as this would be the focus of a separate study. In this sentence, we aim to explain the increase in NPP, likely linked to the expansion of plant communities into newly ice-free areas, resulting from glacier retreat driven by increased liquid precipitation and rising temperatures.*

Figure 4: I may repeat my comment from my first review: "What is the point of the thresholds here? Where do they derive from? What is the reason for the scale of annual

precipitation? Where is the "Antarctic limit" in the map? Where do the colors of the scales reflect on the map? This whole figure needs to be revised and to be made clear. "The gradients of these three variables decrease from left to right"? If annual precipitation decreases from left to right, something is wrong with your scale." In your answer, you said you revised the figure according to another reviewer's suggestions. The only change I see is that you changed the colors for NPP.

A: *Dear Reviewer, as previously mentioned, we initially aimed to represent all environmental variables in a single figure. However, based on your feedback, it seems this approach did not achieve the desired clarity. Therefore, we have decided to remove the figure, adjust the order of figure references in the text, and retain the more detailed figures from the supplementary material. Figures 5, 6, and 7 in the supplementary material offer clearer and more detailed information than the removed figure (Figure 4), as they allow for a more focused presentation of SOC stock in relation to each climate variable discussed (temperature, precipitation, and net primary production). If you have any additional suggestions for improvement, we would greatly appreciate your guidance and will make every effort to incorporate your recommendations. We have also updated the figure captions to include a note that the data source is the Chelsa dataset.*

l. 292/293, 313/314 etc. You repeat several times that your results indicate that climate change could enhance the potential of Antarctic ice-free soils to act as carbon sinks. Please remove the repetitions and take care that the complete Results section becomes tighter.

A: *We agree with the reviewer and remove lines 313/314 and revise the results to avoid repetition, verbosity and other minor issues.*

l. 318/319 This is not a special feature of MA or AP.

A: *Dear Reviewer, we would like to clarify that at no point in the text do we state that this characteristic is special and/or unique to MA and AP.*

l. 319-321 Please revise this sentence. This is a very general statement, especially guano phosphatization plays only a role in soils where seabird colonies are present.

A: *We agree with the reviewer and have revised the sentence as suggested*

l. 323-326 Please make clear where the connection to your work is and shorten it.

A: *We agree with the reviewer and have adjusted the sentence according to the recommendations provided.*

l. 330 Again, invasive plants do not contribute to SOC?

A: *We agree with the reviewer and add the following referenced sentence:*

"It is important to note that invasive plants, such as Poa annua, can be contributing to significant SOC inputs, especially in the context of climate change37. However, studies examining the relationship between SOC inputs and invasive plants in Antarctica remain scarce."

l. 323-333 Please shorten this passage and indicate the connection to your work.

A: *The sentence was adjusted following the reviewer's recommendations, as follow:*

"Soil temperature and moisture variability play a crucial role in SOC dynamics as indicated by BIO1, BIO6, BIO12, BIO13, and BIO14 (Fig.4). Thomazini and Mendonça6,13,36, highlighted the link between CO2 emissions and soil temperature and moisture in Antarctica, especially near the 0°C isotherm, with temperature driving carbon mineralization."

l. 333 Reference (12) is not needed.

A: *We agree with the reviewer's suggestion and have removed the reference accordingly.*

l. 336 "...across the areas the studied site"?

A: *The sentence was adjusted following the reviewer's recommendations.*

l. 340-345 This statement needs solid references. You should check the work of Molina-

Montenegro et al. (2019), Bergstrom (2022), Tichit et al. (2024). Especially in the AP and MA region, invasive species should not be neglected.

A: *Indeed, we appreciate the reviewer's valuable input and have revised the sentence to correct the error:*

"Although it has recently been recognized that invasive species are colonizing parts of Antarctica following glacier retreat[39] and altering certain soil characteristics[38], they cannot yet be incorporated into models due to the limited availability of reliable future data."

l. 352-353 It is not clear what these uncertainty values refer to as you name uncertainty values for SOC stocks in the following sentence.

A: *We agree with the reviewer and have adjusted the entire sentence by specifying the uncertainties in detail:*

"Specifically, the uncertainty values (MAE) for the 0–5 cm, 5–15 cm, and 15–30 cm soil layers were 37.24, 39.62, and 42.92, respectively, while the RMSE values were 58.37, 61.51, and 69.53, respectively (Fig. 5)."

l. 397-398 This is redundant - both the statement and the sentence.

A: *We have revised the sentence to address the issue pointed out by the reviewer.*

l. 398-401 Again repetitive. Warmer temperatures can also have a negative effect on plant growth, please address this.

A: *We have revised the sentence to address the issue pointed out by the reviewer.*

"Plant biomass inputs in surface soils play a crucial role in changes to SOC stock. As glaciers retreat, they expose new areas for plant colonization, while warmer temperatures enhance the plants' growth[42]. However, extreme heat can also have negative effects on plant growth. Cavieres et al. (2016)[43] demonstrated that leaf temperatures exceeding 20 °C can impair photosynthesis, reducing plants' ability to

tolerate freezing temperatures, which is a critical trait for colonizing harsh environment, such as those formed by glacier retreat. The glacier retreat and plant colonization...”

l. 401, 403 These are general statements that require general references.

A: *Dear Reviewer, we understand your concern but kindly wish to clarify that this passage highlights the connection between areas exposed by deglaciation, plant colonization, and the resulting changes in soil characteristics, such as organic matter and SOC stocks, within the Antarctic environment. This reference was the most pertinent we could find for this context. However, if you have suggestions for a more suitable reference, we would be more than happy to revise and incorporate it into our manuscript.*

l. 404 You give a reference from 1985 to underline the current colonization?

A: *We agree with the reviewer and have replace the reference.*

l. 404-410 Too wordy.

A: *We have adjusted and shortened the sentence in response to the issue raised by the reviewer.*

l. 427 You should add short information what negative carbon-climate feedback means (you don't have to repeat the explanation in the Discussion section).

A: *We adjusted the sentence as requested by the reviewer.*

l. 431 What do you mean by "are poised"?

A: *We adjusted the sentence to make it clear.*

Discussion

l. 442 You use a modeling approach, please attenuate your statements accordingly. "...will be..." indicates that this will happen for sure.

A: *We adjusted the sentence as requested by the reviewer.*

l. 449-461 I still don't see why you need the comparison with the Arctic here. However, if you are convinced you need it, you should massively shorten this passage. I don't see any additional value here in trying to counterbalance the Arctic with its massive C stocks with the rather small ice-free areas in the MA and AP region. Please stick to your recent work and discuss your results.

A: *We agree with the reviewer and have removed the comparative sentences about the Arctic, as well as shortened the text as recommended.*

"Our findings suggest that atmospheric carbon feedback dynamics in certain regions of MA and AP tend toward negative feedback, as the ice-free areas and Cryosols in these regions have lower SOC stocks[4,53]."

l. 462-476 Again, please stick to your recent work and discuss your results. The SOC stocks of the Arctic are not related to your work.

A: *We agree with the reviewer and have removed the comparative sentences about the Arctic, as well as shortened the text as recommended.*

"The size of ice-free areas and pedogenetic factors also influence SOC stocks. In the Antarctic ice-free area (49,500 km2) has an estimated SOC level of 0.725 Pg C in its soils[4]."

l. 481-483 You stated that you could not include data on the proliferation of ice-free areas in your model?

A: *We acknowledge the small mistake in this sentence and thank the reviewer for pointing it out. The sentence has been adjusted accordingly.*

l. 483-498 Please discuss your results and not other researchers' work.

A: *We have revised the sentence in line with the reviewer's request. Should there be any further suggestions concerning this section, we would greatly appreciate additional details and relevant citations to help enhance our discussion.*

l. 499-512 Same here.

A: *We have revised the sentence in line with the reviewer's request.*

l. 521 Why did you not add this in the limitations section?

A: *We agree with the reviewer and have relocated this sentence to the limitations section, along with making other relevant adjustments to the modified sentences.*

l. 537-549 This is not the place to introduce new topics. Why do you mention the soil texture of your samples for the first time here in the last paragraph? You should discuss your results here, but you introduce a completely new topic.

A: *We agree with the reviewer that this initial sentence should not be included in that section. We apologize for the oversight and have removed the sentence flagged as an issue by the reviewer.*

Conclusion

l. 551 Again, it is not appropriate to use "will" here.

A: *We agree with the reviewer and have adjusted the sentence as requested.*

l. 564-570 Again, focus on your recent work - the comparison with the Arctic is not appropriate here as it does not conclude any aspect of your work.

A: *We agree with the reviewer and have adjusted the sentence as requested.*

Methods

l. 580/581 Please give a reference here.

A: *We have added a reference as requested by the reviewer.*

l. 581 "hovering"?

A: *We adjusted the sentence as requested by the reviewer.*

l. 581 "carpets moss"?

A: *We adjusted the sentence as requested by the reviewer.*

l. 581/582 Please give a reference here.

A: *We added a reference as requested by the reviewer.*

l. 582-584 Please give a reference here.

A: *We added a reference as requested by the reviewer.*

l. 584-586 Please give a reference here.

A: *We added a reference as requested by the reviewer.*

l. 599 It should be "World Reference Base for Soil Resources"

A: *We adjusted the sentence as requested by the reviewer.*

l. 628-630 Please rephrase this sentence.

A: *We rewrote the sentence as requested by the reviewer.*

Reviewer #3 (Remarks to the Author):

Authors have appropriately addressed my comments and included my suggestions in the revised manuscript. I do not have any further concerns with this manuscript.

A: *We thank the reviewer for his valuable contributions to this manuscript.*