

## Peer Review File

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International Maritime Regulation decreases sulfur dioxide but increases nitrogen oxide emissions in the North and Baltic Sea.



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*Web links to the author's journal account have been redacted from the decision letters as indicated to maintain confidentiality*

21st Aug 23

Dear Mr Van Roy,

Your manuscript titled "Assessment of the international maritime regulations' impact in the North & Baltic Sea" has now been seen by 2 reviewers, and we include their comments at the end of this message. They find your work of interest, but some important points are raised. We are 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. In particular, for publication in Communications Earth & Environment, we require that you:

\*Present novel insights into the impact of international maritime regulations on air pollutants, based on evidence that is presented in the context of clearly communicated study aims.

\* Outline your methodology at a level of detail that will allow an independent researcher to replicate your research.

\* Discuss your results in the wider context of existing tools and models

Please highlight all changes in the manuscript text file.

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:

[link redacted]

\*\* 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,

Martina Grecequet PhD  
Associate Editor,  
Communications Earth & Environment  
On Twitter: @CommsEarth

## EDITORIAL POLICIES AND FORMATTING

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.

Editorial Policy: [Policy requirements](https://www.nature.com/documents/nr-editorial-policy-checklist.pdf) (Download the link to your computer as a PDF.)

Furthermore, please align your manuscript with our format requirements, which are summarized on the following checklist:

[Communications Earth & Environment formatting checklist](https://www.nature.com/documents/commsj-phys-style-formatting-checklist-article.pdf)

and also in our style and formatting guide [Communications Earth & Environment formatting guide](https://www.nature.com/documents/commsj-phys-style-formatting-guide-accept.pdf).

\*\*\* DATA: Communications Earth & Environment endorses the principles of the Enabling FAIR data project (<http://www.copdess.org/enabling-fair-data-project/>). We ask authors to make the data that support their conclusions available in permanent, publically accessible data repositories. (Please contact the editor if you are unable to make your data available).

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:

- Unique identifiers (such as DOIs and hyperlinks for datasets in public repositories)
- Accession codes where appropriate
- 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 [a](#)

<http://www.nature.com/sdata/policies/repositories>

If a community resource is unavailable, data can be submitted to generalist repositories such as [figshare](https://figshare.com/) or [Dryad Digital Repository](http://datadryad.org/). 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 article “Assessment of the international maritime regulations’ impact in the North & Baltic Sea.” By Ward Van Roy et al., addresses the impacts of SO<sub>2</sub> and NO<sub>x</sub> shipping emission regulations. These regulations are in place to provide significant health and environmental benefits. Nevertheless, the effectiveness of such regulations is an open question. Therefore, Ward van Roy et al. are addressing this gap through an analysis of measured ship plumes, ship inspection and compliance report results and satellite data. The most important findings are that the regulations had no effect on NO<sub>x</sub> emission; on the contrary, their study reveals that NO<sub>x</sub> pollution has risen in the past three years. For SO<sub>2</sub>, the regulations are very effective and emissions are decreasing. Their findings highlight the need for more effective regulations to address ship emissions, especially for NO<sub>x</sub> emissions. The claims by Ward Van Roy et al. can be considered as novel due to the in-depth analysis of multiple sources of data (fixed and mobile measurements, ship inspection in ports and compliance reports, satellite data). They take into account the most recent and relevant literature in the field and also include findings from very recent research projects. Although there has been evidence on the subject of effective SO<sub>2</sub> regulations in contrast to mostly ineffective NO<sub>x</sub> regulations, Ward Van Roy et al. are performing for the first time an in-depth analysis of all available data, applying best practice methods, including well performed statistical analyses of the data applied. These findings are of high interest for the scientific community in the field of ship emissions and concentrations, as well as for policy stakeholders that should tackle the need for stricter NO<sub>x</sub> emission regulations in the shipping sector.

The applied data and methods are convincing and the authors take into account the most relevant data available to perform such an assessment. As mentioned, the statistical analysis of the data applied is well done. The consideration of seasonal effects in analysis of VCD from satellite is taken into account to make sure that seasonal effects are not biasing the measured signals. In addition, the effects of a general decrease of Cov19 effects as well an increase due to geopolitical events (War in Ukraine, higher prices for fuels) are discussed.

The discussion of the effectiveness of SECA results reflects well the results and underlines the need “to maintain vigilant” in terms of checking for compliance, due to a slight trend for non-compliance

in recent years (probably due to higher fuel prices). Also in terms of the spatial distribution of SECA effects there are more studies necessary, which could eventually lead to more robust results for high-risk areas (close to coast, in ports).

The discussion in terms of NECA effectiveness, points out that potential non-compliance is increasing, which has already been pointed out by other studies. Nevertheless, the study by Ward van Roy et al. emphasize again that “the absence of a comprehensive EU regulatory framework specifically addressing NOx emissions from shipping with inspection rules can be considered a critical factor” and that for example in Canada there are efforts to tackle this problem.

The TROPOMI satellite data is discussed in the light of Cov19 impacts in the research period as well as land-based sources and the robustness of identifying signals from shipping from TROPOMI columns.

Eventually, the study recommends a revision of current NOx regulations, implementation additional NOx regulation and more stringent effective enforcement measures in the Baltic and North Sea but also the need to introduce an additional NECAs in the North Atlantic.

In the discussion, I miss a section on how atmospheric transport modeling (or chemistry transport modeling) could support the findings in addition to satellite data, fixed and mobile measurements as well as non-compliance reports. Although the underlying data is enormous, it would make sense to at least address/discuss the possibility of including regional or global scale models to strengthen the outcomes of this study. This might be of major importance for policy makers. We should use all available tools to send a clear message!

This is my only critique. Besides this, it is an easy to follow manuscript. Only sometimes abbreviations, specific methods or devices are not introduced properly (see minor remarks). Taking into account that the manuscript is submitted to Communications, I would suggest to reduce streamline the document for some redundant parts in the introduction, results and discussion.

I recommend publication with minor revisions. Congratulations to the authors for this great scientific work.

#### Minor remarks:

Ln 37 - Introduce so2 and nox in introduction

Ln 76/77 – it would be of interest for which years satellite data is used

Ln 105 – you should introduce what a sniffer is

Ln 120 – and airborne measurements, typically located where?

Ln 295 – bracket missing

line 315 – what is BAQPZJR?

Line 339/340 – BAQPZJR introduction should happen in line 315

Line 352 – title needs to be changed from SO2 to NO2

Ln 422 – again: what is a sniffer? Introduce it

#### Reviewer #2 (Remarks to the Author):

Review Manuscript COMMSENV-23-0957-T

The manuscript titled “Assessment of the international maritime regulations’ impact in the North & Baltic Sea.” conducted a comprehensive analysis of the effectiveness of international regulations to cut ocean-going vessels’ emissions in the European SECAs and surroundings areas. The study is structured by exploring data from different sources (remote measurements, satellite data, data archives etc.), and performing spatiotemporal analysis at different scales, with a robust statistical

analysis. The overall approach is consistent and well-defined with a detailed methodology, providing an exhaustive overview within the scope of the work and a valuable discussion of the findings. Anyway, the structure should be modified in its sections because of difficult ability in reading and understanding the development of the work in its parts in the current form (see in the following). Finally, I think the paper is a potential very good work, however, needs making little improvements before publication. After that, in my opinion, it could be suitable for publication and could provide significant indication on the current situation of the sector by proposing emissions' limits to be strengthened, new ECAs or other measures to reduce air pollution from shipping.

#### Minor revisions

- A list of acronyms is highly suggested to make more readable the text.
- Introduction. It is well written and exhaustive about the topic, by explaining the study context, the central research question as well as the scope of the work. However, I'd like to suggest a small change, by moving lines 58-62 at the beginning of line 39.
- Methods. This section is quantitatively important and it should be moved after the Introduction and not at the end of the manuscript, to get more understandable the subsequent results and discussion.
  - Regarding fitting of the emission data, explicit the significance of the factors a, b, c, k, n, o, p within the formulas (7) and (8).
  - Line 537: correct with "[...] annual compliance monitoring data from four fixed monitoring sites and eight airborne [...]"
  - Lines 697-698: delete the sentence "By looking at the absolute differences, areas with high pollution levels are more prone to be emphasized." and explain better the similar sentence at the following lines 699-700.
- Figures. All of them miss captions.

In addition:

- Missing opening brackets in the form "[...] figure x)" in the text. Please, check it.
- Figures 2, 6: check typing error in the legend, axis titles.
- Were mean yearly non-compliance results for each area (reported in Fig. 5 A-B) weighted for number of inspections/fuel samples?
- Figure 11 should be improved i.e., with a scale bar, indication of States etc.
- Insert colour scale in Figure S.8
- Figures S.10 and S.11 could be resumed by plotting in a single graph only the differences per month between after and before entering into force NECA.
- Figure S.12 reported the same results of Figure S.10 and S.11, did not it? If yes, please check and remove Figure S.11.

#### Other Minor revisions

- Line 352: correct "SO<sub>2</sub>" with "NO<sub>2</sub>"
- Correct "nm" with "m" throughout the manuscript and figures i.e., for distance to port/SECA border.

# Response to reviewers

**Manuscript nr: COMMSENV-23-0957-T**

**Title: Assessment of the international maritime regulations’ impact in the North & Baltic Sea**

The authors wish to thank the reviewers for their thorough evaluation and important feedback. The comments of the reviewers have all been carefully considered and where taken into account where possible. Please find our reply to each of the comments below. We have replied to every comment in italics font. When a substantial revision of the text of manuscript was required we provided the modified section highlighted in yellow. A track-changes document (pdf) is provided together with the revised manuscript. In addition as the article is a chapter of the doctoral dissertation of the main author, some additional changes have been made to meet the comments of the jury.

## Editorial comments

\*Present novel insights into the impact of international maritime regulations on air pollutants, based on evidence that is presented in the context of clearly communicated study aims.

*Reply:*

\* Outline your methodology at a level of detail that will allow an independent researcher to replicate your research.

*Reply:*

\* Discuss your results in the wider context of existing tools and models

*Reply:*

## Reviewer #1 – General remarks:

The article “Assessment of the international maritime regulations’ impact in the North & Baltic Sea.” By Ward Van Roy et al., addresses the impacts of SO<sub>2</sub> and NO<sub>x</sub> shipping emission regulations. These regulations are in place to provide significant health and environmental benefits. Nevertheless, the effectiveness of such regulations is an open question. Therefore, Ward van Roy et al. are addressing this gap through an analysis of measured ship plumes, ship inspection and compliance report results and satellite data. The most important findings are that the regulations had no effect on NO<sub>x</sub> emission; on the contrary, their study reveals that NO<sub>x</sub> pollution has risen in the past three years. For SO<sub>2</sub>, the regulations are very effective and emissions are decreasing. Their findings highlight the need for more effective regulations to address ship emissions, especially for NO<sub>x</sub> emissions. The claims by Ward Van Roy et al. can be considered as novel due to the in-depth analysis of multiple sources of data (fixed and mobile measurements, ship inspection in ports and compliance reports, satellite data). They take into account the most recent and relevant literature in the field and also

include findings from very recent research projects. Although there has been evidence on the subject of effective SO<sub>2</sub> regulations in contrast to mostly ineffective NO<sub>x</sub> regulations, Ward Van Roy et al. are performing for the first time an in-depth analysis of all available data, applying best practice methods, including well performed statistical analyses of the data applied.

These findings are of high interest for the scientific community in the field of ship emissions and concentrations, as well as for policy stakeholders that should tackle the need for stricter NO<sub>x</sub> emission regulations in the shipping sector.

The applied data and methods are convincing and the authors take into account the most relevant data available to perform such an assessment. As mentioned, the statistical analysis of the data applied is well done. The consideration of seasonal effects in analysis of VCD from satellite is taken into account to make sure that seasonal effects are not biasing the measured signals. In addition, the effects of a general decrease of COV19 effects as well an increase due to geopolitical events (War in Ukraine, higher prices for fuels) are discussed.

The discussion of the effectiveness of SECA results reflects well the results and underlines the need “to maintain vigilant” in terms of checking for compliance, due to a slight trend for non-compliance in recent years (probably due to higher fuel prices). Also in terms of the spatial distribution of SECA effects there are more studies necessary, which could eventually lead to more robust results for high-risk areas (close to coast, in ports).

The discussion in terms of NECA effectiveness, points out that potential non-compliance is increasing, which has already been pointed out by other studies. Nevertheless, the study by Ward van Roy et al. emphasize again that “the absence of a comprehensive EU regulatory framework specifically addressing NO<sub>x</sub> emissions from shipping with inspection rules can be considered a critical factor” and that for example in Canada there are efforts to tackle this problem.

The TROPOMI satellite data is discussed in the light of COV19 impacts in the research period as well as land-based sources and the robustness of identifying signals from shipping from TROPOMI columns.

Eventually, the study recommends a revision of current NO<sub>x</sub> regulations, implementation additional NO<sub>x</sub> regulation and more stringent effective enforcement measures in the Baltic and North Sea but also the need to introduce an additional NECAs in the North Atlantic.

In the discussion, I miss a section on how atmospheric transport modeling (or chemistry transport modeling) could support the findings in addition to satellite data, fixed and mobile measurements as well as non-compliance reports. Although the underlying data is enormous, it would make sense to at least address/discuss the possibility of including regional or global scale models to strengthen the outcomes of this study. This might be of major importance for policy makers. We should use all available tools to send a clear message!

This is my only critique. Besides this, it is an easy to follow manuscript. Only sometimes abbreviations, specific methods or devices are not introduced properly (see minor remarks). Taking into account that the manuscript is submitted to Communications, I would suggest to reduce streamline the document for some redundant parts in the introduction, results and discussion.

#### Reply to the general comments:

*The authors wish to thank the reviewer for the extensive reading and positive feedback. The manuscript has been revised and streamlined as suggested, all minor remarks have been addressed. In addition a discussion on the topic of air quality modelling has been added in the discussion.*

The research findings coming forth of this study emphasize the need to review the current air quality models that include ship emissions. These models should accurately incorporate both the real world emission factors reflecting actual ship emissions and the observed compliance levels at sea, accounting for spatial variations within the ECAs. By updating these models, valuable insights can be gained on the health impact of shipping. Such understandings can subsequently serve as a driving force for policymakers to reconsider and improve the prevailing international regulatory framework.

**Minor remarks:**

Ln 37 - Introduce so<sub>2</sub> and no<sub>x</sub> in introduction

Reply: *This has been corrected in the revised manuscript*

Ln 76/77 – it would be of interest for which years satellite data is used

Reply: *This has been clarified in the revised manuscript*

Ln 105 – you should introduce what a sniffer is

Reply: *This has been clarified in the revised manuscript, also reference was made to the supplementary material with an extensive description of the sniffer measurement technique*

Ln 120 – and airborne measurements, typically located where?

Reply: *This has been clarified in the revised manuscript:*

The temporal analyses reveal notable disparities in non-compliance rates between fixed stations (1.0%), typically situated near ports, and airborne measurements (5.3%) typically conducted in the territorial waters and the Exclusive Economic Zones (EEZ) (figure 1)

Ln 295 – bracket missing

Reply: *This has been corrected in the revised manuscript*

line 315 – what is BAQPZJR?

Reply: *This has been corrected in the revised manuscript*

Line 339/340 – BAQPZJR introduction should happen in line 315

Reply: *This has been corrected in the revised manuscript*

Line 352 – title needs to be changed from SO<sub>2</sub> to NO<sub>2</sub>

Reply: *This has been corrected in the revised manuscript*

Ln 422 – again: what is a sniffer? Introduce it

*Reply: This has been clarified in the revised manuscript*

#### **Reviewer #2 General remarks:**

The manuscript titled “Assessment of the international maritime regulations’ impact in the North & Baltic Sea.” conducted a comprehensive analysis of the effectiveness of international regulations to cut ocean-going vessels’ emissions in the European SECAs and surroundings areas. The study is structured by exploring data from different sources (remote measurements, satellite data, data archives etc.), and performing spatiotemporal analysis at different scales, with a robust statistical analysis. The overall approach is consistent and well-defined with a detailed methodology, providing an exhaustive overview within the scope of the work and a valuable discussion of the findings. Anyway, the structure should be modified in its sections because of difficult ability in reading and understanding the development of the work in its parts in the current form (see in the following). Finally, I think the paper is a potential very good work, however, needs making little improvements before publication. After that, in my opinion, it could be suitable for publication and could provide significant indication on the current situation of the sector by proposing emissions’ limits to be strengthened, new ECAs or other measures to reduce air pollution from shipping.

#### *Reply to the general remarks*

The authors wish to thank the reviewer for the valuable insights and meticulous comments provided in the review. As a general comments we would like to emphasize that we are bound to the journal guidelines regarding the formatting of the publication. This means that the methods and materials have to be provided in a section at the end of the article. This is very specific for all Nature publications and might indeed not be the standard format for scientific publications. Also the authors had to adjust to these editorial guidelines. Nevertheless we believe that in print form, this formatting provides a clear and direct article highlighting the results and conclusions while providing all relevant technical information for reproducing the findings in the final section. For more information on the guidelines for the authors please visit:

<https://www.nature.com/documents/commsj-phys-style-formatting-guide-accept.pdf>

#### **Minor remarks**

- A list of acronyms is highly suggested to make more readable the text.

*Reply: A list of acronyms is unfortunately not accepted by the journal guidelines.*

<https://www.nature.com/documents/commsj-phys-style-formatting-guide-accept.pdf>

*If the reviewer would like to see a list of acronyms, I can gladly refer to the doctoral dissertation which consists of a list of acronyms*

<https://surv.naturalsciences.be/d/febc494a4bcc49a58079/>

- Introduction. It is well written and exhaustive about the topic, by explaining the study context, the central research question as well as the scope of the work. However, I'd like to suggest a small change, by moving lines 58-62 at the beginning of line 39.

*Reply: The authors agree with the reviewer suggestions and have changed this in the revised manuscript.*

- Methods. This section is quantitatively important and it should be moved after the Introduction and not at the end of the manuscript, to get more understandable the subsequent results and discussion.

*Reply: Also here the authors respectfully would like to refer to the formatting guidelines of Nature Communications Earth and Environment, which specifically state that the methods and material should be provided after the results and discussion:*

<https://www.nature.com/documents/commsj-phys-style-formatting-guide-accept.pdf>

- Regarding fitting of the emission data, explicit the significance of the factors a, b, c, k, n, o, p within the formulas (7) and (8).

*Reply: Both fittings were revised and better aligned, also the factors are explained in the revised manuscript*

- Line 537: correct with "[...] annual compliance monitoring data from four fixed monitoring sites and eight airborne [...]"

*Reply:*

*We received data from 9 airborne operations:*

*NL (Heli), BE (AC), DE (RPAS), DK (RPAS+AC+Heli), FR (RPAS), LT (RPAS), ES (RPAS)*

*For DK the Heli and RPAS data was combined as it was made using the same mini-sniffer technology. It is correct that only data from 8 airborne operations were used (LT was omitted) , but all data from the fixed sites were used*

*We received data from 5 fixed sites: DE (3), NL (1), DK (1). Germany has 3 sites, two in the North Sea and 1 in the Baltic Sea. The caption of Table S.2. was revised to clarify this*

- Lines 697-698: delete the sentence "By looking at the absolute differences, areas with high pollution levels are more prone to be emphasized." and explain better the similar sentence at the following lines 699-700.

*Reply: this was corrected in the manuscript*

- Figures. All of them miss captions.

*Reply: The figure captions are provided in the manuscript text on the position the figures are supposed to be introduced. This is due to the submission system which requires to provide the figures separately and the captions in the main manuscript.*

In addition:

- Missing opening brackets in the form “[...] figure x)” in the text. Please, check it.

*Reply: This recurring error has been corrected in the revised manuscript*

- Figures 2, 6: check typing error in the legend, axis titles.

*Reply: The legends of figure 2 were corrected and the axis of figure 6 were corrected. Also the legends and axis of the related supplementary figures were corrected.*

- Were mean yearly non-compliance results for each area (reported in Fig. 5 A-B) weighted for number of inspections/fuel samples?

*Reply: Yes these are the overall compliance results from all EU countries per area combined. The caption was adjusted to clarify this.*

- Figure 11 should be improved i.e., with a scale bar, indication of States etc.

*Reply:*

- Insert colour scale in Figure S.8

*Reply:*

- Figures S.10 and S.11 could be resumed by plotting in a single graph only the differences per month between after and before entering into force NECA.
- Figure S.12 reported the same results of Figure S.10 and S.11, did not it? If yes, please check and remove Figure S.11.

*Reply: The reviewer is correct, figure 12 combines figures 10 and 11, the reason why the different figures were used is to visualise the seasonality before and after the NECA came into effect. When Figures 10 and 11 are displayed separately it is easier to compare the difference in NO<sub>x</sub> between the areas. Due to the redundancy we agreed to remove figures 10 and 11 for the revised manuscript.*

Other Minor revisions

- Line 352: correct “SO<sub>2</sub>” with “NO<sub>2</sub>”

*Reply: This has been corrected in the revised manuscript*

- Correct “nm” with “m” throughout the manuscript and figures i.e., for distance to port/SECA border.

Reply: *In maritime regulations, nautical miles (nm) is more commonly used. The reviewer is however correct that for scientific purposes, the international metric system is more appropriate. Therefore, where international regulations are concerned, the nm is kept, but for all other distances, km is used in the revised manuscript (e.g. distance to port).*

22nd Sep 23

Dear Mr Van Roy,

Your manuscript titled "Assessment of the international maritime regulations' impact in the North & Baltic Sea" has now been seen by our reviewers, whose comments appear below. In light of their advice we are delighted to say that we are happy, in principle, to publish a suitably revised version in Communications Earth & Environment under the open access CC BY license (Creative Commons Attribution v4.0 International License).

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

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

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

Best regards,

Martina Grecequet PhD  
Associate Editor,  
Communications Earth & Environment  
@CommsEarth

REVIEWERS' COMMENTS:

Reviewer #1 (Remarks to the Author):

All comments addressed, I recommend publication.

Reviewer #2 (Remarks to the Author):

Thanks to authors to properly address every revision I suggested.

In this form, in my opinion, the manuscript is suitable for publication in "Communications earth and environment".