

## **Answer to reviewer comments**

Manuscript title: DeepOWT: A global offshore wind turbine data set derived with deep learning from Sentinel-1 data

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Reviewer comments are colored blue, our answers are colored black.

### **Reviewer-1:**

*Reviewer-1 general impression:*

The paper presents a novel method to identify the location and development stages of offshore wind turbines, at a global scale, for the period 2016-2021, using radar imagery of the Santinel-1mission. The methods proposed employs deep learning based object detection, linking the SyntEO approach for automatic synthesis of large annotated training data and a cascade of two convolutional neural network models. This allowed the identification of, first, the offshore wind farm areas, and second, the offshore wind farm turbines. The detection of OWT development stages was realized by applying two consecutive peak finder algorithms to the swap profiles of the time series imagery.

The data generated and method used are new, the workflow is thoroughly documented and described with sufficient detail. The resulted DeepOWT data set is openly available in a readily usable format compatible with geo-spatial software like QGIS. One strong aspect is the comparison of the resulted data set with the OSM database and the GOWT v1.3 data set, which validates and emphasizes the advantages of the resulted Deep OWT data set. The identified locations of OWTs are also consistent with the data provided by other open-source data repositories such as EmodNET.

The research is highly relevant in the context of the accelerated energy transition, leading to the high scale deployment of offshore wind farms. The results can represent valuable inputs in large-scale environmental impact assessments of renewable infrastructure, at a global scale. This can contribute to a more coherent, strategic and knowledge-based decision-making process related to future deployments of OWFs, when considering potential impacts on the marine environment. Furthermore, an updated data-base of OWFs and their development status can refine the outputs of regional and global energy models.

Dear Anonymous Referee #1,

thank you for your time and effort in reviewing our manuscript. We are happy to hear your positive feedback on the implemented method for deriving a global offshore wind infrastructure data set from Sentinel-1 data. We are very happy about the agreement that the presented data set is an important contribution to the large-scale studies that will take place in the context of increasing activity in the offshore wind farm sector and are pleased to be able to contribute with this data set.

Kind regards,

Thorsten Hoeser

## **Reviewer-2:**

### *Reviewer-2 general impression:*

The work should be completed at various points. From this perspective, the authors should work to improve the manuscript and prepare it for a journal publication. Some (Minor) of the changes required are

Dear reviewer-2, we are very grateful for your time and effort in reviewing our manuscript. We are happy to hear that minor changes are required to improve the manuscript in order to prepare it for a journal publication. Please find below a point-by-point response to each of the ten issues raised. We have uploaded our revised manuscript via the submission system. Changes colored in yellow, in the manuscript version with track changes, refer to revision remarks, changes marked in blue indicate modifications in language to improve the reading flow as requested in revision remark 2. For a detailed list of all changes made and a point-by-point answer to all revision remarks, we refer to the attached PDF in this answer.

### *Reviewer-2 revision remarks:*

**Remark 1:** In the abstract, the main challenges should be described briefly and then the main proposed solutions should be mentioned. It is not necessary to discuss the details of the gaps.

Thank you for bringing our attention to this issue. After rereading the abstract, we agree that the first part of the abstract can be reduced to focus more on the motivation, methodology used, and the data product presented. Hence, we have rephrased the abstract to narrow the focus to these three major aspects.

**Remark 2:** An additional English grammar and spelling check should be performed. Moreover, some sentences have to be reformulated in order to present in a clearer way the ideas and the findings of the proposed work.

We are very grateful for the thorough revision. In order to improve the language used in the manuscript and make the content described more comprehensible, we have, as requested, revised the entire manuscript regarding the use of language. All changes are marked in blue in the revised version of our manuscript with track changes.

**Remark 3:** Each acronym should be explained the first time it appears in the text, even if it appeared in the abstract. Checks all abbreviations in text: each word should start with capital to explain an abbreviation. Add a table with the title to the article. Note: The list of abbreviations should be in alphabetical order

We want to thank the reviewer for this helpful comment, which leads to a better reading experience of the manuscript. We closely checked the manuscript regarding the use of acronyms. Whenever an acronym is used the first time, it is now explained at this point by using capital letters in its long version. Furthermore, we compiled table 1, which explains all acronyms and abbreviations in alphabetic order. As requested, the table can be found at the beginning of the document.

**Remark 4:** The “2 Related Research” background section is very weak. Authors should develop this section properly by reading new articles and references about “Sentinel 1” and “CNN”. In the introduction, please list the main contributions of this paper and the research question, and the motivations. What are the main advantages to select CNN?

Thank you for this important remark. We are happy for the opportunity to provide more background regarding this topic. The originally proposed related research section focuses on the thematic side of the manuscript, which is the detection of and data sets about offshore marine infrastructure and offshore wind farms. The introduced research from earlier publications gives an overview of how marine infrastructures have been extracted from remote sensing data and, most important, which data sets of offshore wind energy infrastructure are available. However, we are glad to hear that the manuscript raises the general interest in applying CNNs for investigating Sentinel-1 data. We are happy for the opportunity to introduce a new subsection 2.1 “Deep learning based image analysis in Earth observation“ in the related research section, which broadens the related research section to cover the application of deep learning on Earth observation with a focus on CNNs and Sentinel-1 data, as requested by reviewer-2.

In order to improve the related research section, we added literature concerning CNNs and their application in remote sensing with a specific focus on CNNs applied to investigate Sentinel-1 data. We also state why we decided to use CNNs for offshore wind energy infrastructure detection, as requested by reviewer-2, see line 63 ff. We end the related research section by providing a summary of the motivation and contribution of this research paper, see line 105 ff.

**Remark 5: Line 25> “also affects stakeholders”, Please give some examples of such as stakeholders.**

Thank you for making us aware of this formulation which has to be more explicit. As requested, we provided examples of affected stakeholders such as the fishing industry, shipping routes, military exclusion zones, cultural heritage, residents of coastal areas or the recreational industry. Furthermore, since the number of potential stakeholders and competing interests can become very large and diverse, ranging from the social sector over economic interests to the ecologic domain, we added an additional source (Virtanen, E. et al.: Balancing profitability of energy production, societal impacts and biodiversity in offshore wind farm design, Renewable and Sustainable Energy Reviews, 158, 112087, <https://doi.org/10.1016/j.rser.2022.112087>, 2022), which provides an overview of potential multi-use conflicts, to wrap up the already provided examples which focus on specific aspects.

**Remark 6: Line 63> “offshorewind”, Please check. Can be “offshore wind”**

We checked and corrected it. Thank you again for your very detailed revision. Your remarks are highly welcome!

**Remark 7: Figure 7> Please check the horizontal axis of figure 7 “ quarterly time series”.**

We changed the label to ‘quarterly intervals’

**Remark 8: Line 365> “by” can be deleted.**

We deleted “by”

**Remark 9: All formulas must be transferred to the methodology section. Are these formulas part of the results of your research?**

Thank you for your comment regarding the mixing of methodology and results. We moved the methodological description of the evaluation process to the methods section 3.2.4 “Data set evaluation” to make clear that the formulas are not part of our results but the methodological description of the evaluation process. The presented scores and formulas are established evaluation scores, the cited source of Padilla, R. et al.: A Comparative Analysis of Object Detection Metrics

with a Companion Open-Source Toolkit, Electronics, 10, <https://doi.org/10.3390/electronics10030279>, 2021, provides a good overview of their usage. They are not our results, nor have we invented them. However, to provide proper documentation, especially of micro and macro averaging of the F1 score and to avoid confusion during the interpretation of the evaluation metrics, we decided to show how we calculated the evaluation metrics explicitly.

[Specify the Materials and Methods section and the results section of your research. "It can be developed based on the following: Introduction, Case Study, Materials and Methods, Results, and Conclusion. Display the article with a better structure."](#)

We are very grateful for the feedback on the manuscript's structure. While drafting the original manuscript, we decided on a structure that emphasises the submission's data set aspect. Thus some unconventional sections appear in the manuscript structure. However, similar structures are not unusual for articles published in Earth System Science Data (ESSD). Nevertheless, we agree that after the "Introduction" and "Related research" sections, a "Materials and methods" section contributes to a proper and more intuitive manuscript structure. We combined the old sections Data, Methodology, Ground truth data sets and the earlier mentioned subsection about the methodological side of the data set evaluation into one section called "Material and methods", as requested by reviewer-2. Dedicated subsections structure this new overarching section to introduce single aspects of used materials and applied methods.

However, ESSD also has some instructions regarding the manuscript's structure and content that we must take into account. For instance, "ESSD data descriptions should [...] emphasise the quality, usability, and accessibility of the dataset, database, or other data product and should describe extensive carefully prepared metadata and file structures at the data repository." To comply with the journal's scope and general requirements, we kept the old sections like "Technical description" and "Potential data set applications", but aggregated them in an overarching "Results" section in order to follow the remarks of reviewer-2. Furthermore, a dedicated "Data availability" section is mandatory in ESSD articles. Thus section 5 "Data availability" appears after the "Results" section and before the concluding section at the end of the restructured manuscript. The reorganised manuscript structure is:

Abstract

Introduction

Related research

- Deep learning based image analysis in Earth observation

- Offshore wind turbine detection in Earth observation imagery

Materials and methods

- Materials

- Methodology

  - Synthetic training data set generation with SyntEO

  - Global OWT object detection with CNNs

## Time series analysis for deployment dynamics and location refinement

### Data set evaluation

#### Results

Evaluation results

Data set comparison

Technical description

Potential data set applications

Data availability

Conclusions

Author contributions

Competing interests

Acknowledgements

References

We have decided not to highlight the restructuring in the manuscript with track changes, as otherwise, almost all text blocks would be highlighted, and other changes to the body of the text would not be easy to follow. To still recognize the restructuring easily, we presented the new structure above in a comprehensible way.

We want to thank reviewer-2 for the very helpful and constructive revision remarks. We are glad to have received your scientific support during the manuscript submission process and want to express our gratitude for the effort and time you put into the revision of our manuscript.

Sincerely Thorsten Hoeser