

June 18th 2021

Dear Editor,

Please find the revised and resubmitted manuscript "*In situ* observations of turbulent ship wakes and their spatiotemporal extent", for consideration for publication in the Ocean Science Special Issue "Shipping and the Environment – From Regional to Global Perspectives". As described by e.g. the two articles by Jalkanen et al. in the special issue, shipping gives rise to chemical, biological and energy pollution. The present manuscript provides another piece to the puzzle of shipping environmental impact studies, introducing characterization of ships' turbulent wakes, which is essential for future understanding of distribution of shipping related chemical and biological pollution from ships and shipping lanes. Regarding energy pollution, while previous studies have focused on ship noise and shoreline erosion/wash, the present manuscript introduces the perspective of ship induced turbulent mixing, supported by observations of mixing down to 30 m depth in the wake.

Studies of ship wakes require an interdisciplinary approach and bridging of the gap between fine-scale hydrodynamics and larger scale physical oceanography. From the thorough review process of the previous two submitted versions of the manuscript, and also feed-back from the scientific community e.g. at the EGU 2021 conference, we have realized that most marine scientists have never considered the potential importance of ship induced turbulence, nor has it been considered by the naval architects specializing in hydrodynamic modeling of ship propulsion. This situation implies that the challenges are not limited to the analytical aspects of bridging spatiotemporal scales used in different disciplines, but the reviews have been strongly influenced by current available knowledge on adjacent topics, which has rather led to a development of the manuscript away from the core scope. For example, requests have been made to include possible induction of sediment resuspension in the manuscript, which then implies that description of the Kelvin wakes needs to be included. This in turn shifts the focus away from the turbulent wake, which is the scope of the article. We believe that this is partly explaining the comment in the last review round, where it is suggested that section 3.3 and 3.4 could be more concisely written. In this revised version, we have therefore aimed at returning to the focus of the scope of the manuscript.

Finally, we recognize that we initially underestimated the complexity of the subject. Yet we believe that this very first manuscript, based on a larger data set than any previous studies on turbulent ship wakes (see table 1 in the revised manuscript), highlights that previous assumptions in literature cannot be verified in data from *in situ* observations. Further, we can show that the duration of the wake signatures calls for consideration e.g. when collecting data by ferrybox setups in shipping lanes; a temperature deviation of up to one centigrade is important to have knowledge about when interpreting ferrybox data.

Detailed responses to the Editor's and Reviewers' comments are provided in the Authors' response to reviewers' comments. All the revisions made can be seen in the uploaded manuscript with tracked changes.

Looking forward to hearing from you.

Yours sincerely,

Amanda Nylund on behalf of all the co-authors

Nr.	Review comment	Author's answer	Changes in manuscript. All references to row numbers refer to the manuscript with tracked changes included.
1	<p>While the authors explain the reasoning behind choice of the two different study regions and two different techniques, there is still confusion on how the analysis of the Gothenburg Harbour and Bornholm shipping channel are combined to support the findings of the study. Ultimately these two study areas are independent and disconnected from each other.</p>	<p>The aim of this study was to use two different approaches for studies of the spatiotemporal extent of the turbulent wake. The two methods capture different spatiotemporal scales and thus provide complementary information. Using only one of the methods would not be enough, as none of them cover the entire spatiotemporal range of the wake.</p> <p>As stated in previous review rounds, we initially placed instruments at the Bornholm study site, but they were lost. We agree that by making simultaneous <i>in situ</i> and <i>ex situ</i> observations at the same site, it would be possible to compare and infer between the results from the different methods, which is what we aim to do in future studies.</p> <p>However, in this study we are quantifying different aspects of ship wake dimensions for a large number of ships. For this purpose, we don't consider the different study sites as something that affects the validity/relevance of our conclusions/findings. Rather we use the results of the two approaches as different proxies to study the same phenomenon/process.</p> <p>To address the comment regarding the "<i>confusion on how the analysis of the Gothenburg Harbour and Bornholm shipping channel are combined to support the findings of the study</i>", we have made revisions to further clarify how these two different approaches provide different and complementary information regarding the spatiotemporal extent of the turbulent wake. We have also revised the discussion regarding how the results from the two different methodological approaches relate to each other.</p>	<p>Clarifications made with tracked changes in the following sections:</p> <ul style="list-style-type: none"> • Abstract (row 15-40) • Introduction (row 99-103) • Materials and methods (row 122-136)

2	<p>The numerous classifications of the data create confusion. For example, the ADCP analysis is divided into “wake”, “double”, “close wake”, “no wake”, and “0-3 ship widths”, “3-6 ship widths”, and “6-55 ship widths”. It is unclear why these 6 classifications were used when in the results sections they appear interchangeable i.e., close wake == 0-3 ship widths. Table 3 also has the category of “single” and “all” in addition to “close” and “double”. Finally, the statement “Due to the low detection rate in the two larger distance categories, on the close wake category will be used in graphical presentation ... (line 351)” suggests that it is only the close wake data that has relevance to supporting the finding of the study.</p>	<p>To address this comment the manuscript has been revised to only include the "wake" and "no wake" division, together with the close wake category (now renamed to “close wake subset” instead and the use of the term categories is no longer used in the manuscript).</p> <p>The “double wakes” (induced from more than one ship passing the instrument at the same time) has been fully removed from the dataset presented in the result. We agree that the main conclusions regarding wake depth and longevity are based on the close wake subset, but the detection of wakes passing from further distances also provide information about the spatiotemporal extent of the turbulent wake. Therefore, the results from wakes passing from further distances have been moved to the supplementary information. Since there are no publicly available previous studies with such a large dataset of turbulent wake observations, we consider it important to make these results accessible to the scientific community.</p>	<p>Section 2.1.2 Data analysis (row 191-218, 248, 261, 273-279)</p> <p>Section 3.1 Gothenburg harbour study (row 361-372)</p> <p>Section 3.1.3 Wake detection rate (row 388-393)</p> <p>Section 3.1.4 Maximum wake depth (row 406-420, 426-434)</p> <p>Table 2. (row 423-424)</p> <p>Fig 7 (row 474)</p> <p>Section 3.1.5 Temporal wake longevity (row 479-492)</p> <p>Fig 8 (row 496).</p>
3	<p>The supporting figure and table could be improved. For example, Figure 4 caption identifies “ships visible as warmer yellow dots”, these are very hard to find. For easy of identification, it would have been appropriate to draw a box around these features.</p>	<p>The figure has been changed to a different figure, in which the ships and wakes are indicated more clearly. The figure also gives a description of the detection and digitalization process.</p>	<p>Figure 4 has been changed (row 345).</p>
4	<p>X-axis of figures 6,7 and 8 could have been given as $F (x10^7 \text{ kg m/s}^2)$.</p>	<p>The x-axis title on figure 6, 7, and 8 have been changed to $F (x10^7 \text{ kg m/s}^2)$.</p>	<p>The x-axis title of figures 6,7 and 8 have been revised.</p>
5	<p>The sections 3.3 and 3.4 could be more concisely written.</p>	<p>Section 3.3 and 3.4 have been revised and written more concisely. Some of the paragraphs have been moved to other sections of the manuscript and some sections have been removed. Several of the paragraphs/parts of the paragraphs had been added/extended in response to comments from reviewers. It is clear that the topic of the turbulent wake can be viewed from many angles and there are many different aspects that could be discussed in relation to our results. In this revised version of the manuscript we have returned to a clearer focus on the parts we consider within the scope of the current study, which has led to us removing some of the paragraphs/sections written in response to previous reviewer comments. We have tried to find a balance between being more concise and responding to the comments we have received.</p>	<p>See track-changes document for the revised version of section 3.3 and 3.4 (Number of rows reduced from 252 to 167).</p> <p>Paragraph from original section 3.4 revised and moved to section 3.1.4 (row 445-471)</p>
6	<p>The conclusion of ship wake impact on the large-scale marine environment is not strongly supported given the local impact of ship wake from both in in-situ (ADCP) and satellite SST study.</p>	<p>We humbly object to this statement, as we have not made any extrapolations/claims of the “ship wake impact on the large-scale marine environment”. Based on our results, we conclude that regional (i.e. not large-scale) effects in areas with intense ship traffic cannot be excluded, but further</p>	

		studies are needed to determine when and where these effects are non-negligible.	
7	The grammar needs to be improved, as use of the word "it" without an antecedent noun is difficult for a native English speaker to parse. In many other languages, such a vague word is not an issue. In English conversational speaking the word "it" pops up and is understood in context. However, in writing, there are no gestures or social cues as to what this word "it" is referring to.	The use of the word "it" has been revised throughout the manuscript.	See track-changes document.