Reviewers response on "Tracking Marine Debris in Northwest Spain: Assessing Wind Influence with a Lagrangian Transport Model."

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Reviewer 2

The article addresses a topic of considerable environmental and scientific relevance: the transport and accumulation of plastics in estuarine systems under wind influence. The study combines Lagrangian simulations with varying windage coefficients to evaluate seasonal accumulation patterns, residence times, and correlations with river discharge in the Ría de Arousa (NW Spain). The work is well-structured, and the results are consistent with previous literature, providing valuable insights into the processes governing the retention of marine debris in estuarine environments. Nonetheless, before publication, several aspects require clarification and further detail, particularly with respect to methodological details and contextual framing. Overall, I recommend the manuscript for publication, subject to minor revisions.

We really appreciate your comments. Please find below the detailed answers to each one.

Some points that I believe require clarification or improvement:

1. Introduction

In the manuscript, the distinction between macro- and microplastics is presented in centimetres. However, the standard unit, used in the literature, is typically millimetres, as indicated in the references cited by the authors themselves (Min et al., 2020; Wayman & Niemann, 2021). I recommend aligning this definition with the units in the literature, to avoid terminological inconsistencies.

This has been updated in the newer version of the paper.

2. Study Area

The criteria used to divide the study area into the sections shown in Figure 1 are not clearly explained. Does this segmentation arise from hydrodynamic differences, socio-economic characteristics, or another specific parameter? The authors should clarify the rationale behind this segmentation to justify its relevance.

This has been clarified in the document. They were constructed by tracing perpendicular lines along the axis of the estuary. After first reviewer comments, we have modified the regions so now they have approximately the same area all of them. Consequently all figures were recalculated.

While I understand the choice to present simulations for winter (DJF) and summer (JJA), as these represent extreme conditions, it would be advisable to also include wind roses for the intermediate seasons (MAM and SON) in Figure 2, in order to provide a more comprehensive view of the seasonal variability of the wind patterns analysed in the study. Additionally, since the results also refer to these intermediate seasons, their inclusion would be pertinent. Considering that the entire study is based on particle discharge proportional to the flow of the Ulla River, it would be important to provide, in this section, information on the average, minimum, and maximum river discharge values.

Thanks for your comment. We added the four wind roses into the text. As you may see, autumn and spring roses are an intermediate stage to winter and summer roses where the south western and north eastern winds are more pronounced.

3. Input Data

Although the Numerical Methods section specifies that simulations were performed using 2D surface fields, I consider that this information should also appear in the Input Data section. This would prevent the reader, upon first encountering the description of the hydrodynamic model, from assuming that vertical processes or particle sinking were also considered. A simple statement indicating that only 2D surface fields were used would make the methodology clearer from the start.

This has been added in the newer version of the paper.

4. Numerical Methods

The adoption of an 80 % beaching probability is a central aspect of the study, yet the manuscript does not provide the rationale for this choice. It would strengthen the work if the authors explained this choice in more detail. I understand that a high retention rate may be associated with rocky coasts and intertidal zones, where stranded plastics tend to remain longer due to lower remobilization. However, in the correlation section (Table 1), the analysis focuses mainly on sandy beach segments, where higher remobilization would be expected. Therefore, it would be useful to clarify this apparent discrepancy and discuss the choice of the 80 % value for the different types of coast included in the study.

The beaching probability allows us to evaluate different coastal locations where beach retention varies. In particular, for the MOHID-Lagrangian model, the only option is to apply a single beaching probability for the entire coastline, which is also unfair. Cloux et al. (2022) simulated alternative beaching probabilities for the same location but under different initial conditions. In this study, to investigate the impact of wind on particle drift and beaching, we used the worst-case scenario (80 %).

A key element of the work is the analysis using different windage values (cw = 1 %, 3 %, and 5 %). However, this choice could be better supported with additional references or, ideally, observational data. Providing such justification would increase the robustness and relevance of the adopted parameterization (e.g., https://doi.org/10.1016/j.envint.2020.105655 and https://doi.org/10.1038/s41598-018-22939-w).

Thanks for your suggestions. Both references have been added to the description of the study case.

5. Results and Conclusion:

Figure 3 is not entirely informative. The current colour palette limits the ability to discern differences between areas of higher particle accumulation, which reduces the figure's interpretative value.

Thanks for your comment. We have modified this figure in the manuscript.

The authors state that particles tend to concentrate upstream due to the Coriolis force. While this is correct, it would be helpful to explicitly relate it to the resulting residual circulation. Including a figure illustrating the residual circulation would significantly enhance the discussion and provide clearer mechanistic insight.

How water enters and leaves the Ría de Arousa (and other Galician rías) is significantly influenced by the Coriolis effect. The northern edge has a greater surface outflow of river water, which encourages beaching. Coriolis force's impact on the Galician Rías has been extensively studied for a long time. In the paper, we include a brief remark and a few references on that.

There are also concerns regarding the discussion of the results, which primarily focuses on a single winter and a single summer scenario with different windage values. Given that, particle release is substantially higher in winter, Figure 5 appears largely redundant. If the goal is to assess whether beaching is more frequent in summer or winter and under varying windage conditions, it would be more scientifically robust to compare scenarios with similar particle release rates across seasons. Alternatively, considering particle age—the time from release to beaching—across all scenarios would provide a more meaningful and grounded comparison.

Addressing these points would greatly strengthen the manuscript by clarifying the drivers of particle accumulation and providing a more rigorous basis for seasonal and windage-related comparisons.

While Figure 5 is not among the most central results of our study, we believe it provides valuable information regarding the correlation between particle release and coastal arrivals. A higher number of released particles does not necessarily imply a greater number of beaching events. Seasonal dynamics may coincide with periods of higher particle release and, at the same time, promote transport mechanisms that drive particles away from the coast. This interplay between emission timing and hydrodynamic conditions is precisely what we aim to explore in this analysis

Very interesting suggestion. We have calculated the time lags of all particles beaching at different locations. New figure 6 and Table 1 show these results. The distribution of time periods between emission and beaching are shown in the figure. They fit well to a Weibull distribution as expected since wind and surface currents drive particles. The most frequent time lags (mode of the distribution) are shown in Table 1 for different wind coefficients. As stated in the paper some interesting differences were observed in time lags, even in between close locations.

The definition and discussion of residence time appears to be somewhat unclear. From my perspective, this parameter seems strongly influenced by the size of the areas considered and the number of particles released. In principle, a larger number of particles or a more extensive area would tend to increase residence time, but this relationship is not necessarily true from a hydrodynamic standpoint. Moreover, the calculations also appear to depend on the initial time of the simulation and the number of particles released. For example, if the simulation begins in January, the residence time estimated for this first month will inevitably be shorter than in March—not due to hydrodynamic conditions or wind, but simply because fewer particles are present to be account for.

The simulations were conducted over a continuous 5-year period to capture the seasonal and monthly variability of the tracers. Since the entire 5-year simulation was performed in a single run, any potential bias in the initial month would be compensated over the subsequent years. Moreover, the estimated residence times are below 4 days, which suggests that the results are unlikely to be significantly affected by any initial bias.

The interpretation of Figure 6 is also not entirely clear. In the innermost zone of the estuary, residence time may be higher due to proximity to the source. In the intermediate zone, however, since particles that return to this area are counted again, the probability of this occurring is naturally higher, particularly, given the way the estuary has been subdivided. This hypothesis could be further supported by including a figure showing the Eulerian residual circulation of velocities, which would provide better context for the results. Additionally, according to the methodological criterion that particles leaving the study area are considered "dead," the downstream region is excluded from the residence time calculation, which limits interpretation for this outer area. Therefore, it would be important to clarify how residence time was computed or, alternatively, to explicitly highlight these limitations in the discussion to avoid potentially biased conclusions.

For the residence time calculation, we have considered that the fact that particles re-entering a subregion does not cause any bias, but provides a more solid statistic on the mean residence time for each region. As mentioned in the new version of the manuscript, we have taken into account particles that didn't strand. Then, we consider the time that each particle spends in each subregion. Also, as you have mentioned, particles that exit the domain are no longer taken into account, as they are no longer computed in our simulations. This fact has now been explicitly highlighted in the newer version of the manuscript.

I would encourage the authors to explicitly discuss the limitations of the implemented methodology. For instance, it is not clear whether a horizontal resolution of 300 m is sufficient, considering the dimensions of the zones chosen as accumulation areas. Similarly, the potential effects of three-dimensional processes should be addressed: to what extent might a 3D simulation alter the results compared to the current approach?

Thanks for the suggestion, further discussion discussion has now been added to the conclusions in the newer version of the manuscript.

The role of waves in particle distribution within the estuary, as well as in the beaching process, also warrants consideration, since they may significantly influence particle trajectories and residence times.

Within the estuarine, the effect of waves is really small, that's why we didn´t consider it in this paper. Please see the Wave Atlas elaborated by the regional meteorological office (MeteoGalicia) https://www.meteogalicia.gal/web/modelos-numericos/atlas-de-ondas for more details.

Finally, it would be valuable to discuss the generalizability of the methodology: how could it be applied to other study areas, and are there comparable studies in different regions that support or challenge the current approach? Addressing these points would strengthen the manuscript by providing a clearer context and by acknowledging the methodological constraints.

This discussion has now been added to the conclusions section of the manuscript.