Reply to comments by Reviewer 1

This study is thorough and well designed, and the manuscript is generally very well written.

I recommend publication after considering the comments and suggestions below.

We would like to thank the reviewer for the constructive comments and suggestions that clearly improved the manuscript and its readability. We have made the corresponding changes in the manuscript and respond to each of the comment below in orange. Line numbers correspond to the new version of the manuscript.

The first sentence in Introduction reads:

"Ocean connectivity is a fundamental process in the marine system." However, connectivity is not a fundamental process in itself, but rather the property or outcome of fundamental processes such as transport/advection. Thus this sentence should be reformulated.

We agree with this comment and reformulated this first sentence to: "Ocean connectivity arises from fundamental physical processes such as the transport and exchange of water masses" (ll.27)

Figure 1:

- For readers without connection to the Bay of Biscay area, it might be a little hard to locate this area. I would suggest to include a little more land to the east and west of the given area, and perhaps also a little to the south and north.

Thank you for this suggestion. We added a subfigure of a larger area within the northeast Atlantic to place the Bay of Biscay in a broader context.

- The legend uses the short names "fr_shelf", "es_slope" etc, which are also defined in the text. These shortnames make sense in the programming/analysis phase, as names of files and figures etc. However, I am not sure if these shortnames are needed in the manuscript, as it might be clearer to simply write explicitly (also in this legend) as "Frensh shelf" and "Spanish slope" etc. This goes throughout the paper. The exception might be Figures 7-9 where compact representation is needed. The shortnames could be defined and used for these figure labels. I will not insist on this change, but it could be considered.

Thank you for this suggestion. We changed the names of the subsection as suggested in the text and in the figure captions wherever possible. Only in Figure 7-9 we used abbreviations Fr. shelf/slope and Sp. shelf/slope.

We also decided to rename “deep” to “basin” as we thought this may be a better understandable label for the deep basin.

Section 2.2, line 125:
Ocean model resolution is specified as 1/36 degree of longitude and latitude. It would be useful to also say what this refers to in km, approximately since one degree of longitude depends on the latitude.

It is also a general thing throughout the paper that distances are given in degrees of longitude and latitude. Most places (like here) it would be good to also give the corresponding distance in km. E.g. line 128 says that particles are seeded on 0.08 x 0.08 degree grid - however, this gives different spacing northwards and eastwards. This is not a problem in itself, but should be made more clear by specifying also distances in km.

Yes, it is correct that the spacing difference in longitude and latitude. To highlight this, we added the distances in kilometers, as suggested by the reviewer:

… at 1/36° horizontal resolution (about 3.1 km in latitude and 2.1-2.2 km in longitude), … (ll. 145-146)

on a regular 0.08° × 0.08° grid (about 8.9 km × 5.9-6.5 km) (ll. 148-149)

Section 2.2, line 137. I would suggest to rewrite these to sentences to something like:

“The model configuration included no wind drift or diffusion, and a time step of 15 minutes. Particles hitting the coast were not stranded/removed, but left in place to move ashore once the current has an offshore component.”

Thank you for this suggestion, the specifications are indeed much better stated and explained this way. We change these two sentences to this suggested formulation. (ll. 160-161)

Section 2.3, line 156: “preceding two months”

Thanks for the comment and to highlight the confusion here. Actually “ preceding three months” is correct, as we use integration times of 90 days for every particle, regardless of when during the month it was seeded. This means, the particles seeded on the first of the seeding month provide information of the preceding three months, whereas the particles seeded at the end of the month are influenced by the circulation of the seeding month and the preceding two months.

We slightly reformulated this sentence to:
“Please note that the results for the 90-day integration time thereby integrate over the circulation during the seeding month and the preceding three months, while the results for 7- and 30-day integration times are mainly influenced by circulation during the seeding month and the previous month (Fig. 2).” (ll. 185-187)

And we additionally clarified this now by adding a more detailed description of the integration time at the beginning of 2.3:

“Since Lagrangian simulations are run backward in time, they reveal the transport pathways and the origin of the particles considering a specified integration time. From each 120-days simulation, we extract particle positions at integration times of 7, 30 and 90 days to reflect key physical and ecological timescales (Fig. 2). The integration time is defined relative to the release date of each particle, to analyze all trajectories together that were seeded throughout one seeding month and experience the same duration of backward simulation. This means that for a 90-day integration, particles seeded at the beginning of a month capture the preceding three months, whereas those seeded at the end of the month capture the seeding month and the preceding two months. The 30-day and 7-day integrations expand over the seeding month and the previous month depending on the release date.” (ll 164-172)

Figure 3: Again it might be a little hard to locate the area, as both land and ocean are white. It could be considered to put a color (black?) on land. But this is hard to know without testing, and thus authors can decide what they think is best.

Okay, we thank the reviewer for this suggestion and changed the land color to grey in all figures.

Figure 4: Lines for 200 and 1000 m isobats are very close, indicating that the shelf is quite steep. This could be commented on somewhere.

Okay, we commented on this in the definition of the subareas:

“…and the French and Spanish slopes (French slope, Spanish slope, depth = 200–1000 m), characterized by steep topography and closely spaced isobaths that act as a topographic barrier to exchanges between the shelf and the deep ocean.” (ll. 114-116)

Section 3.2, line 258: Although ODI is defined earlier, I would suggest to remind the reader that it means Origin diversity index.

Okay, we added the full name of the ODI here:
“In this section, we characterize particle connectivity using two metrics: the mean

transit time between seeding positions and origin subareas, and the Origin Diversity Index (ODI), which quantifies the mixing of distinct particle origins."

Section 3.2, line 268: within "2-5 degrees" is again a little vague, since a degree of longitude is different from a degree of latitude. This is another example where distances in km would be better.

Thanks for this comment. We reformulated the distances in kilometers to have a more accurate description of the distance the particles travel. But we added the degrees (ranges for longitude and latitude) to keep the degrees for reference in the figure. The text is now changes to:

"90 % of all particles remain within approximately 150-500 km of their subarea of origin over the 90-day period, corresponding to about 1.5-4.5° latitude or 2-7° longitude in the BoB."

We also changed in the same section:
"After 30 days (green colours), particles typically disperse by 20-100 km (approximately 0.25-1° of displacement in latitude and/or longitude) from their origin subarea, with larger distances travelled in specific regions." (ll. 298-299)

Section 3.4, line 361: a trend of -0.0006 degrees N is given, corresponding to 67 meters per month. This sounds like a very small trend although stated as significant,, and also I would think that Figure 10a shows rather a decline until ~2012 and thereafter an increase, i.e. a long term oscillation if anything.

However, more prominent on Fig 10a is the apparent oscillation on ~5 yers scale. This is quite interesting, and should be commented in the text. Could it be related to El Nino or other known indices/oscillations?

Yes, it is correct that this trend is very small, although statistically significant. We reformulated this paragraph to highlight the quasi-periodic oscillations and the decadal variability that shows a decline until about 2012 and a recovery afterwards:

"The time series is characterized by pronounced interannual to multi-year fluctuations (Fig. 10a). This includes oscillations on timescales of 4-6 years, and a progressive decrease until approximately 2012, the strongest negative anomaly in the record, followed by a recovery. Consistent with this overall evolution, a weak but statistically significant negative linear trend of $-0.0006°$ N month^{-1} is detected over the full 30-year period ($p = 0.015$, 95 % confidence level), indicating a slight long-term reduction in the northward penetration of Spanish shelf waters." (ll. 399-403).

Regarding the link to climate variability, it is true that there may be a link. It is true that the roughly 5 day cycle may hint to some links to El Niño, and also that ENSO may affect the North Atlantic through remote teleconnections, but the influence for the Bay of Biscay is much less direct and we have not found literature that mentions any links between variability in the Bay of Biscay and ENSO. However, previous studies have been looking at the impact of NAO and EA on the circulation and hydrography in the Bay of Biscay.

We added a small discussion on the potential link with climate variability: "The multi-year oscillations found in the northward extent of the Spanish shelf waters (Fig. 10a) may reflect the influence of large-scale climate variability. In the BoB, Borja et al. (2019) describe how atmospheric teleconnection patterns, particularly the North Atlantic Oscillation (NAO), modulate wind conditions that influence upwelling, regional currents, and river-plume dispersal, all of which may affect connectivity. Previous studies have linked the interannual variability of the IPC and its wintertime expression in the BoB to large-scale atmospheric variability, particularly the NAO (Garcia-Soto et al., 2002; Garcia-Soto, 2004; Le Cann and Serpette, 2009; Le Hénaff et al., 2011), while relationships with the EA (eastern Atlantic) and other teleconnection patterns have also been reported (Esnaola et al., 2013; Manso-Narvarte et al., 2018). However, these relationships are not systematic, suggesting that no single climate index consistently explains the variability of the regional poleward circulation. The transport metrics considered here integrate the effects of multiple physical processes, including changes in shelf circulation, slope currents, and basin-scale circulation, making attribution to any single climate mode beyond the scope of the present study." (ll. 497-507)

Comentado [NS1]: Is this a satisfying change for the reviewer?

Section 4, line 383: The paper/simulations uses model surface currents without additional wind drift, which is fine. However, "floating marine litter" is here mentioned, and which is known to need additional wind drift which can be quite significant (typically ~3% of wind). Thus, I would agree that results are valid for microplastics (and plankton etc), but I would comment that connectivity including wind drift could be quite different. E.g. floating plastics is also subject to stranding whenever onshore winds/waves.

Comentado [NS2]: Change everything to contamination?

Thanks for pointing out this inconsistency. We have now used the term marine litter more carefully, exchanged it in the introduction with the term marine contaminant to include also microplastics, chemicals and oil "anthropogenic material such as marine contaminants (e.g. submerged litter, microplastics, chemicals or oil)" (line 32) and further when interpreting the results to its application we specified that we are talking about neutrally-buoyant material.

In Section 4, we replaced floating marine litter with “dissolved contaminants” in:
“Second, surface velocities are the most representative of the horizontal transport of many passive tracers, such as dissolved contaminants, biomass, planktonic organisms, and eDNA, whose dispersal is largely governed by near-surface advection and Lagrangian transport processes.” (ll. 420-422)

Later in the discussion we explained specifically that we are only considering currents without wind so that it is more applicable to neutrally-buoyant particles and dissolved contaminants and that wind has to be considered for floating material:
“Regarding marine litter, there is clear evidence that the southeastern BoB acts as an accumulation zone, influenced by regional circulation patterns, riverine inputs, and winds (Alfaro-Ortega et al., 2025; Ruiz et al., 2022b, Basurko et al. 2022). The retention patterns identified here may contribute to such accumulation; however, floating debris is additionally affected by wind- and wave-driven transport as well as stranding at the coast, which is not represented in our simulations. Consequently, our results are more directly applicable to submerged particles and dissolved contaminants. For floating marine litter, previous studies in the BoB have shown that windage can substantially modify transport pathways and accumulation patterns, increase coastal strandings of highly buoyant items for windage above 3 %, and shift aggregation zones relative to those predicted from currents alone (Ruiz et al., 2022a,b; Bertin et al., 2026).” (ll. 511-518)

Further, we noted at the end of the discussion that the web application that will accompany this paper can potentially be expanded to include simulations with wind included for a broader application.

“The application also provides a foundation for future extensions of the connectivity atlas. Incorporating additional processes such as wind forcing, Stokes drift, and coastal stranding would broaden the applicability of this connectivity atlas to transport of material and organisms influenced by these processes, such as floating marine litter, floating macroalgae, pleustonic species (e.g. *Physalia physalis* and *Velella velella*), as well as to operational applications including search-and-rescue and marine pollution assessments.” (ll. 533-537)

In reference to previous relevant studies about marine litter, for general connectivity and discussion that have actually investigating marine litter, we kept the term marine litter.