

RESPONSE TO ANONYMOUS REFEREE #2

“Influence of model spatial resolution on Sargassum beaching predictions along the Mexican Caribbean coast” by de Santos Medina et al.

Review, Referee #2:

Summary of the Manuscript

This manuscript investigates how ocean model horizontal resolution affects short-term predictions of Sargassum transport and coastal strandings in the Mexican Caribbean. The authors compare 5-km and 1-km ROMS simulations and use the resulting surface currents, together with ERA5 winds, to drive Lagrangian particle simulations in OpenDrift. Four 10-day cases representing different circulation regimes are examined, and forward and backward FTLE fields are used to characterize transport pathways and attracting/repelling structures.

The results suggest that the two model configurations generally produce similar large-scale transport pathways and comparable overall stranding percentages and arrival times, while larger differences occur during the tropical cyclone case and near regions with complex coastal geometry. The authors therefore argue that a 5-km model may be adequate for short-term regional Sargassum forecasting under typical conditions, whereas a 1-km model provides additional value during extreme events and in complex coastal regions.

The topic is relevant and the modelling framework is potentially useful for operational Sargassum forecasting. However, several methodological and interpretational issues should be addressed before the main conclusions can be fully supported.

Major Comments

1. The operational conclusion appears too strong given the limited number of cases. This conclusion is based on four selected 10-day cases rather than a systematic evaluation over the full simulation period, and the particle beaching predictions are not directly validated against observed Sargassum landings. The drifter comparison in Appendix A is useful for evaluating particle advection and windage, but it is not a validation of Sargassum beaching forecasts. I suggest moderating the operational claim (e.g., 'may be sufficient for reproducing broad regional transport patterns under the conditions examined here') or expanding the analysis to a larger set of events and, ideally, comparing predicted landing patterns with available observations.

2. The comparison does not isolate horizontal resolution as the only difference between the two model configurations. The manuscript frames the experiment primarily as a 5-km versus 1-km resolution comparison, but the two ROMS configurations also differ in domain size, number of vertical levels, bathymetric/coastline representation, and boundary forcing: the 1-km model is nested within the 5-km simulation, whereas the 5-km model is forced by Mercator. These differences may influence circulation and coastal transport independently of nominal horizontal grid spacing. The authors should clearly acknowledge this limitation and, where possible, demonstrate that the reported differences are primarily attributable to horizontal resolution rather than other configuration differences. The wording throughout the manuscript should be adjusted accordingly.

3. The temporal resolution of the ocean currents needs clarification, especially given the interpretation of submesoscale processes. The Methods state that daily surface currents are used for particle simulations, whereas later the manuscript states that currents are updated every 6 h. This inconsistency should be resolved. If daily currents were used, the interpretation of storm-induced and submesoscale variability should be reconsidered because important high-frequency processes may not be represented.

4. The interpretation of mesoscale/submesoscale effects requires stronger support and should be better connected to recent Sargassum literature.

Several differences in particle trajectories and landings, particularly during Tropical Cyclone Lisa, are attributed to mesoscale/submesoscale structures and their associated retention or dispersion. These interpretations are plausible but appear to rely largely on visual inspection of the FTLE fields. FTLE structures alone may not be sufficient to demonstrate that these features are submesoscale or wind-driven. The authors could provide additional dynamical diagnostics, such as relative vorticity or Rossby number, or otherwise use more cautious terminology. The discussion would also benefit from recent studies directly examining the role of ocean currents and eddies in Sargassum transport and aggregation, such as Zhang et al. (2024) and Zhang et al. (2025). These two studies also provide relevant support for the statements made in the first sentences of the second and third paragraphs of the Introduction.

Zhang, Y., Hu, C., McGillicuddy Jr., D. J., Barnes, B. B., Liu, Y., Kourafalou, V. H., et al. 2024. Pelagic Sargassum in the Gulf of Mexico driven by ocean currents and eddies. *Harmful Algae*, 102566.

Zhang, Y., Barnes, B. B., McGillicuddy Jr., D. J., and Hu, C., 2025. Sargassum Enrichment in Mesoscale Eddies of the Great Atlantic Sargassum Belt. *Geophysical Research Letters*, 52(7), e2025GL114601.

5. The definition of particle stranding and the release strategy require stronger justification. Particles are considered stranded when they cross the 50-m isobath, which is not necessarily equivalent to actual beaching. Since the study draws operational conclusions about Sargassum beaching, this proxy should be better justified and its limitations discussed. In addition, the uniform release of particles along 85°W is useful for transport-pathway analysis but does not represent the highly heterogeneous spatial distribution of real Sargassum. The authors should clarify that the simulations primarily assess potential transport sensitivity rather than realistic Sargassum biomass or beaching probability.

6. The validation results deserve more discussion. Appendix A shows that the 5-km configuration generally has higher Liu–Weisberg skill scores than the 1-km configuration when compared with undrogued drifter trajectories. This is an important result because it demonstrates that higher spatial resolution does not necessarily produce more accurate trajectories. The authors should discuss this finding more explicitly in the main text and explain its implications for the main conclusions.

Minor Comments

1. Please use the terms “beaching”, “landing”, “stranding”, and “nearshore accumulation” more consistently, especially because the numerical criterion is crossing the 50-m isobath rather than actual coastline contact.

2. The authors should clarify whether 1 km and 5 km refer to nominal grid spacing or effective model resolution.

3. Please provide a clearer quantitative definition of the four cases, especially the “Mean Circulation” and “Large Ro” cases. A small table summarizing wind speed, current speed, Rossby number, and relevant eddy properties would be useful. The selection criteria for the four case studies should be made more quantitative. In particular, explain how ‘Mean Circulation’ and ‘Large Ro’ were objectively defined and whether these periods are representative of their respective regimes.
4. It is unclear whether tidal forcing is included in the ROMS simulations. This should be stated explicitly, given the importance of nearshore and channel circulation in the study region.
5. The omission of horizontal diffusion should be discussed more carefully. Unresolved dispersion may be particularly important in the coarser-resolution model.
6. Please clarify whether particles are deactivated immediately after crossing the 50-m isobath.
7. The statement that the 1-km model can improve “associated biomass estimates” should be reconsidered, since biomass is not explicitly simulated in this study.
8. For the Tropical Cyclone case, the manuscript attributes changes to wind-driven submesoscale structures. It would be helpful to clarify whether the daily/6-hourly ocean-current forcing used in OpenDrift can adequately retain the relevant rapidly evolving circulation signals.
9. Several statements infer likely Sargassum landing locations directly from high FTLE values. Please make clear that FTLE identifies attracting/repelling Lagrangian structures, whereas actual landing also depends on coastal geometry, particle forcing, and the adopted stranding criterion.
10. Lines 68-69: The authors are encouraged to add the following reference to support the description “Multidisciplinary efforts have been undertaken to develop Sargassum forecasting systems at basin and seasonal scales, mainly focused on the tropical Atlantic”.

Putman, N. F., R. T. Beyea, E. G. Ackerman, J. Trinanes, M. L. Henaff, C. Hu, and R. Lumpkin (2025). Systems to monitor and forecast pelagic Sargassum inundation of coastal areas across the North Atlantic: present tools and future needs. *Harmful Algae*, 149, 102933, <https://doi.org/10.1016/j.hal.2025.102933>

Triñanes, J., C. Hu, N.F. Putman, M.J. Olascoaga, F.J. Beron-Vera, S. Zhang, and G.J. Goni. 2021. An integrated observing effort for Sargassum monitoring and warning in the Caribbean Sea, tropical Atlantic, and Gulf of Mexico. Pp. 68–69 in *Frontiers in Ocean Observing: Documenting Ecosystems, Understanding Environmental Changes, Forecasting Hazards*. E.S. Kappel, S.K. Juniper, S. Seeyave, E. Smith, and M. Visbeck, eds, A Supplement to *Oceanography* 34(4), <https://doi.org/10.5670/oceanog.2021.supplement.02-26>.

Hu, C., B. Murch, B. B. Barnes, M. Wang, J-P. Marechal, J. Franks, D. Johnson, B. Lapointe, D. S. Goodwin, J. M. Schell, and A. N. S. Siuda (2016). Sargassum watch warns of incoming seaweed, *Eos*, 97(22):10-15, <http://dx.doi.org/10.1029/2016EO058355>

Reply to Referee #2:

Thank you very much for your review. We are very pleased to receive your major and minor comments. Please find below our answers and the modifications on the manuscript (in red) related to each of your comments. The insertions and modifications are referred to the line numbers of the preprint.

Replies to Major Comments

Response to Major Comment #1: We agree that the operational implications of our results were overstated given the scope of our analysis and that it is important to acknowledge that our conclusions are limited to the cases examined. Further research involving a larger number of case studies or a systematic assessment over the full simulation period is needed to evaluate the generalizability of our findings. Furthermore, we agree that the drifter comparison presented in Appendix A should not be interpreted as a direct validation of Sargassum beaching predictions. Rather, it was used to assess the influence of windage on the ability of the transport model to reproduce observed particle trajectories. We also acknowledge that our results are subject to the assumption that Sargassum exhibits drift behavior similar to that of undrogued drifters. In addition, we did not validate the simulated Sargassum beaching predictions against direct observations of Sargassum strandings for two main reasons. First, satellite-based Sargassum detections near the coastline are subject to uncertainties, including potential false detections caused by factors such as water turbidity and wave breaking. Second, available observations of Sargassum strandings are primarily obtained through initiatives that rely on voluntary reporting, such as Sargassum Monitoring (sargassummonitoring.com), which introduces additional uncertainty regarding the reliability of these observations. Nevertheless, we agree that it is important to acknowledge these limitations and we have revised the manuscript accordingly.

The following modifications were made to the Discussion, Conclusions, and Appendix A:

Lines 390-391: “This study assessed the influence of two ROMS configurations, with nominal horizontal grid spacings of 5 km and 1 km, on short-term predictions of Sargassum strandings in the Mexican Caribbean coast. Four case studies were analysed using a particle transport model in which particles were advected to simulate Sargassum transport.”

Lines 393-396: “Based on four case studies representing different but typical oceanic and atmospheric conditions of the study region, our findings suggest that 5-km-resolution models may be sufficient for operational short-term forecasting, while higher-resolution simulations can provide added spatial detail in specific settings, supporting more effective Sargassum management and mitigation strategies.”

Inserted in line 495: “Moreover, it is important to note that the transport model adopted in this study is an empirical parameterization of Sargassum advection, in which particles are assumed to behave as passive tracers advected at the ocean surface by the combined effect of ocean currents and winds. This parameterization limits the scope of our results, as the optimal windage factor depends on the regional oceanic and atmospheric conditions, the drifter observations used for calibration and validation, and the oceanic and atmospheric forcing fields used to drive the particle advection model (Berline et al., 2020; Johns et al., 2020; Johnson et al., 2020; Lara-Hernandez et al., 2024; Podleski et al., 2023; Putman et al., 2020; Putman et al., 2018). In addition, this approach provides a simplified representation of Sargassum transport because it neglects the inertial effects of Sargassum rafts, which can influence their vertical motion within the water column as well as their interaction with surface winds and oceanic structures

such as mesoscale eddies (Andrade-Canto et al., 2022; Beron-Vera et al., 2015; Beron-Vera and Miron, 2020; Beron-Vera, 2021; Brooks et al., 2019; Miron et al., 2020). Consequently, our findings should be interpreted within the context of the adopted transport model and its parameterization, rather than as a general characterization of Sargassum transport. Assessing whether our conclusions remain valid under alternative modeling frameworks, such as the approach proposed by Beron-Vera and Miron (2020), which explicitly accounts for the inertial effects of Sargassum rafts, remains an important direction for future research. Additionally, comparing simulated particle strandings with observed Sargassum beaching events would provide further validation of the model predictions.

Finally, the findings and conclusions presented in this study are based on four 10-day case studies. Therefore, their applicability is limited to the atmospheric and oceanic conditions represented by these cases. Although the results provide valuable insights within the context of the selected case studies, further research involving a larger number of cases or a systematic evaluation over an extended period (e.g., one year) is needed to assess the robustness and generalizability of the conclusions. Such an extension would help determine whether the findings remain valid under a broader range of atmospheric and oceanic conditions.”

Lines 496-497: “This study evaluated the influence of two ROMS configurations, with nominal horizontal grid spacings of 5 km and 1 km, on short-term predictions of Sargassum strandings in the Mexican Caribbean through Lagrangian simulations of four case studies.”

Lines 511-517: “Our results suggest that for operational and short-term forecasting purposes, using models with a 5 km spatial resolution may be sufficient to represent the general distribution and timing of Sargassum strandings in the region, under the limitations of the conditions represented by the four case studies, and the transport model and particle characterization employed in this study. However, in areas with high geomorphological complexity or during extreme events, the 1-km configuration can provide additional spatial detail and different simulated stranding patterns, although these differences do not necessarily imply improved predictive accuracy. Additionally, a detailed representation of the coastline is essential in simulations, as it directly influences stranding patterns. Ultimately, this study contributes to the development and optimization of more robust forecasting tools that can aid Sargassum collection and mitigation strategies, thereby minimizing its ecological and socioeconomic impacts in the Mexican Caribbean.”

Lines 520-523: “To assess the ability of the particle transport model to reproduce observed drifter trajectories and determine an appropriate windage factor for the simulations representing Sargassum advection, we compared observed trajectories from undrogued buoys of the NOAA Global Drifter Program (Lumpkin and Centurioni, 2019) with simulated particle trajectories driven by surface ocean currents from the 5-km and 1-km ROMS configurations. The transport of...”

Response to Major Comment #2: We agree that our comparison does not isolate horizontal resolution as the only difference between the two ROMS configurations. In addition to their nominal horizontal grid spacing, the configurations differ in domain size, number of vertical levels, bathymetric and coastline representation, and boundary forcing. In particular, the 1-km configuration is nested within the 5-km simulation, whereas the latter receives its initial and boundary conditions from Mercator. We acknowledge that these differences may influence the simulated ocean circulation and particle transport independently of horizontal resolution. Although both configurations were evaluated using the same

atmospheric forcing, particle transport formulation, release strategy, and stranding criterion, we cannot demonstrate that the observed differences are primarily attributable to horizontal resolution alone.

Therefore, we have revised the manuscript to explicitly acknowledge this limitation and clarify that our findings represent the combined influence of the differences between the two model configurations. We have also adjusted the wording throughout the manuscript to avoid attributing the observed differences exclusively to horizontal resolution. Finally, we acknowledge that controlled sensitivity experiments, in which individual model characteristics are varied independently, would be necessary to isolate the specific contribution of horizontal resolution to simulated Sargassum transport and strandings. We remark that our focus was on assessing which of the forecasting configurations is most adequate and whether this choice varies according to oceanic and atmospheric circulation regimes. We have made the following revisions to the manuscript:

Lines 9-11: "...systems. Here, we compare how Regional Ocean Modeling System (ROMS) model configurations with horizontal resolutions of 5 km and 1 km (nominal grid spacing) modulate Lagrangian particle trajectories and subsequent coastal strandings. Four..."

Lines 20-23: "...Cozumel. These findings suggest that, under the environmental conditions represented by the four case studies, the 5-km configuration can reproduce broad particle transport patterns and nearshore arrival distributions comparable to those obtained with the 1-km configuration. However, differences between the configurations become more pronounced during extreme events and in regions with complex coastal morphology, highlighting the sensitivity of simulated nearshore arrival patterns to ocean model configuration. More..."

Lines 75-80: "High-resolution ocean models may improve the representation of circulation processes that influence nearshore Sargassum transport, but their greater computational cost may limit their use in operational forecasting systems. Here, we compare two model configurations with nominal horizontal grid spacings of 5 km and 1 km to evaluate differences in short-term Sargassum transport and simulated strandings in the Mexican Caribbean under four dynamical regimes. By applying the same wind forcing, particle-transport formulation, release strategy, and stranding criterion to both configurations, we assess differences in predicted particle distributions, trajectories, stranding percentages, locations, and times. The main contribution of this study is to identify the dynamical conditions and geographic settings in which the two configurations produce comparable particle transport patterns and to determine situations in which their differences influence simulated Sargassum landings. This comparison provides insights into the sensitivity of short-term particle transport predictions to ocean model configuration and their potential implications for operational Sargassum forecasting systems."

Inserted on line 146: "It is important to note that although the two configurations differ primarily in their nominal horizontal grid spacing, they also differ in domain size, number of vertical levels, bathymetric and coastline representation, and boundary forcing. Consequently, the comparison performed in this study evaluates differences between the two ROMS configurations rather than isolating the effect of horizontal resolution independently of other model characteristics."

Inserted on line 495: "Furthermore, it is important to acknowledge that the two ROMS configurations compared in this study differ not only in horizontal spatial resolution but also in domain size, number of vertical levels, bathymetric and coastline representation, and boundary forcing. These differences may influence the simulated ocean circulation and coastal transport independently of the nominal horizontal

grid spacing. Consequently, the differences observed in particle trajectories and stranding patterns cannot be attributed exclusively to horizontal resolution but should be interpreted as the combined effects of the differences between the two model configurations. A more controlled sensitivity analysis, in which individual model characteristics are varied independently, would be necessary to isolate the specific contribution of horizontal resolution to predicted Sargassum transport and strandings.”

Lines 496-497: “This study evaluated the influence of two ROMS configurations, with nominal horizontal grid spacings of 5 km and 1 km, on short-term predictions of Sargassum strandings in the Mexican Caribbean through Lagrangian simulations of four case studies.”

Response to Major Comment #3: We would like to thank you for your comment and for bringing this inconsistency to our attention. The ocean currents were updated daily for configuring the OpenDrift simulations, and we apologize for our error. We agree that our interpretations that attribute differences to submesoscale processes might be incorrect given the ocean current temporal resolution, therefore we revised the manuscript throughout to avoid attributing differences between the configurations to submesoscale processes. Furthermore, in response to Referee #1, we had added additional diagnostics of Rossby number as an appendix (Appendix B) to support our previous arguments about submesoscale representation in the 1-km configuration, however, after reviewing your comment we retained the appendix to document the enhanced relative vorticity in the 1-km configuration compared to the 5-km configuration, but we have eliminated the attribution to submesoscale processes.

To address the inconsistency on the temporal resolution of the ocean current input, we revised the Methods section (lines 185-186):

“Ocean currents were updated daily and wind fields were updated hourly.”

Regarding the attribution of the differences between configurations to submesoscale processes, we have revised the following sections as follows:

Abstract (lines 15-17): “In contrast, under extreme event conditions (i.e., tropical cyclone), configuration-dependent differences in the small-scale circulation and particle trajectories become larger, leading to substantial shifts in coastal accumulation patterns.”

Results (lines 351-353): “...(2.33% and 2.04%). The Tropical Cyclone case exhibits the largest configuration-dependent differences in particle stranding among the four cases. The Rossby-number analysis presented in Appendix B shows enhanced small-scale vorticity and broader Rossby-number distributions in the 1-km configuration. Together with the configuration-dependent differences observed in the particle trajectories and FTLE deformation patterns, these results suggest that the particle predictions are particularly sensitive to finer-scale circulation variability under tropical-cyclone forcing.”

Discussion (lines 434-438): “The largest differences in particle stranding between the model configurations occur during the Tropical Cyclone case. The Rossby-number analysis in Appendix B indicates enhanced small-scale vorticity and a greater occurrence of large Rossby numbers in the 1-km configuration. The particle simulations also display greater divergence between configurations during this case, with the FTLE fields evidencing corresponding differences in finite-time deformation. Collectively, these diagnostics suggest that short-term particle predictions become more sensitive to differences between the 5km and 1km model configurations when intense atmospheric forcing modifies the small-scale circulation.”

Appendix A (lines 543-545): “This period coincides with the passage of tropical cyclone Lisa across the domain, and the increased divergence between simulated and observed trajectories likely reflects the combined effects of enhanced wind forcing, its impact on ocean circulation, and the enhanced small-scale circulation variability represented by the 1-km configuration, consistent with the Rossby-number analysis presented in Appendix B.”

And the addition of Appendix B as follows (note that this version of the appendix is a modified version of the Appendix B included in the response to Referee #1):

Appendix B

To compare the ocean current fields from the 5-km and 1-km ROMS simulations and assess the enhancement of relative vorticity in the higher-resolution configuration, we calculated maps of the daily-mean Rossby number ($Ro = \zeta/f$) for each of the study cases. The Rossby number was computed as the ratio of the vertical component of the relative vorticity (ζ) of the surface ocean currents to the Coriolis parameter (f). Rossby-number fields were derived from the daily mean surface currents produced by the 5-km and 1-km ROMS configurations. Furthermore, an independently normalized probability density function (PDF) of the Rossby number was calculated for each day, and the daily PDFs were averaged to obtain a mean PDF for each study case and model configuration. The standard deviation (σ), skewness (Sk), 95th percentile (P95), and 99th percentile (P99) were calculated from the pooled Rossby-number values over each study period, while the probability of $|Ro| > 1$ was calculated daily and then averaged over the study period.

Across all case studies (Fig. B1, B2, B3, B4), enhanced relative vorticity and elevated Rossby numbers are observed in the wakes of the islands, particularly downstream of Banco Chinchorro and Cozumel. These wake structures are more confined to the coastline in the 1-km than in the 5-km simulation. Compared with the 5-km, the 1-km simulation also displays numerous narrow filaments around the Islas de la Bahía. In contrast to the wakes downstream of Banco Chinchorro and Cozumel, these filaments are largely absent or poorly resolved in the 5-km simulation.

Although the large-scale circulation patterns are similar in both simulations, the 1-km configuration represents substantially finer elongated bands and filaments of elevated Rossby number. These features are particularly evident around the Islas de la Bahía, the Turneffe Islands, Cozumel, and Banco Chinchorro. During the Tropical Cyclone case (Fig. B2), filamentary structures also develop offshore, extending beyond the immediate coastal environment.

The Rossby-number distributions (Fig. B5) show greater standard deviation in the 1-km configuration than in the 5-km configuration for all study cases (Mean circulation: 0.63 vs. 0.38; Tropical cyclone: 0.36 vs. 0.22; Large Ro: 0.58 vs. 0.38; Anticyclonic eddy: 0.46 vs. 0.30). Skewness is also consistently higher in the 1-km configuration (Mean circulation: 3.07 vs. 0.87; Tropical cyclone: 2.84 vs. 1.33; Large Ro: 2.36 vs. 0.88; Anticyclonic eddy: 3.42 vs. 1.12). The 95th percentile is higher at 1 km for the Mean circulation (0.63 vs. 0.53), Tropical cyclone (0.44 vs. 0.34), and Large Ro (0.70 vs. 0.54) cases, while it is identical for the Anticyclonic eddy case (0.44 in both configurations). The 99th percentile is higher in the 1-km configuration for all cases (Mean circulation: 2.43 vs. 1.47; Tropical cyclone: 1.30 vs. 0.81; Large Ro: 2.10 vs. 1.41; Anticyclonic eddy: 1.69 vs. 1.12). Similarly, the probability of $|Ro| > 1$ is consistently greater at 1 km (Mean circulation: 3.97% vs. 3.20%; Tropical cyclone: 2.23% vs. 0.71%; Large Ro: 4.20% vs. 2.58%;

Anticyclonic eddy: 2.65% vs. 1.88%). Overall, the broader distributions, stronger positive skewness, larger upper-tail percentiles, and increased occurrence of $|Ro| > 1$ in the 1-km simulation are consistent with an enhanced relative vorticity compared to the 5-km simulation.

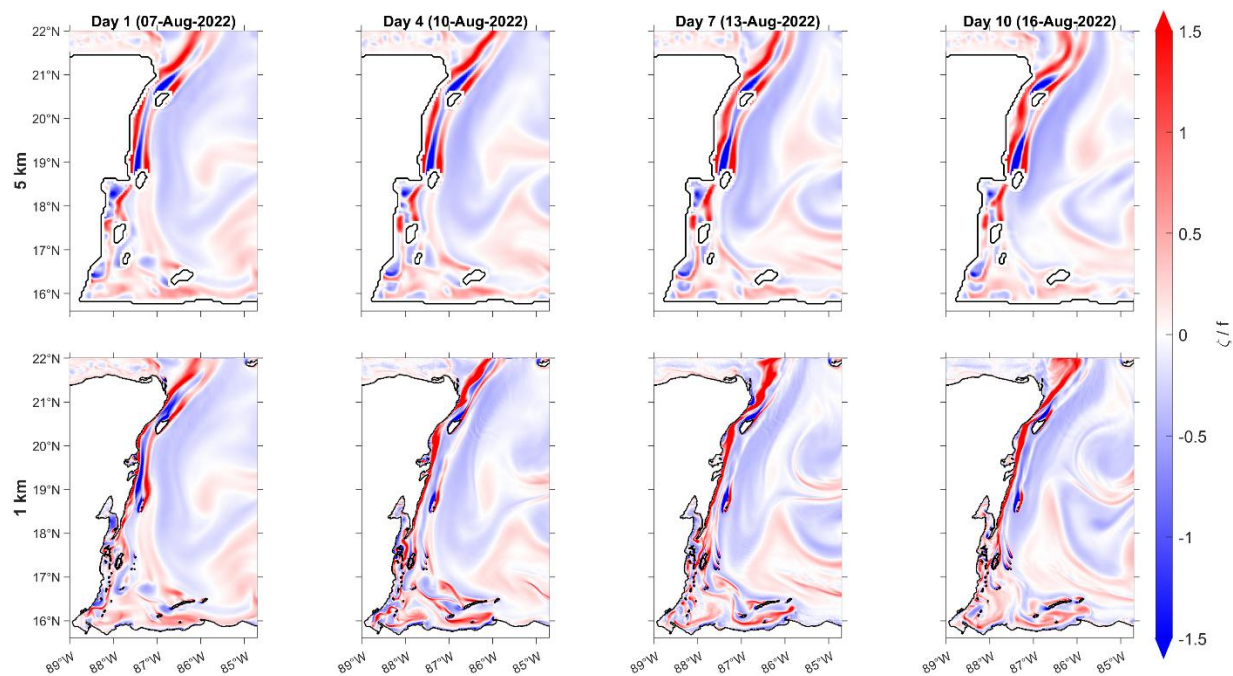


Fig. B1: Daily-mean Rossby number (ζ/f) fields calculated from surface ocean currents simulated with ROMS configured at 5 km (upper panels) and 1 km (lower panels) horizontal resolution. The panels show the daily mean fields for the Mean Circulation (7–17 August 2022) case on simulation days 1, 4, 7, and 10.

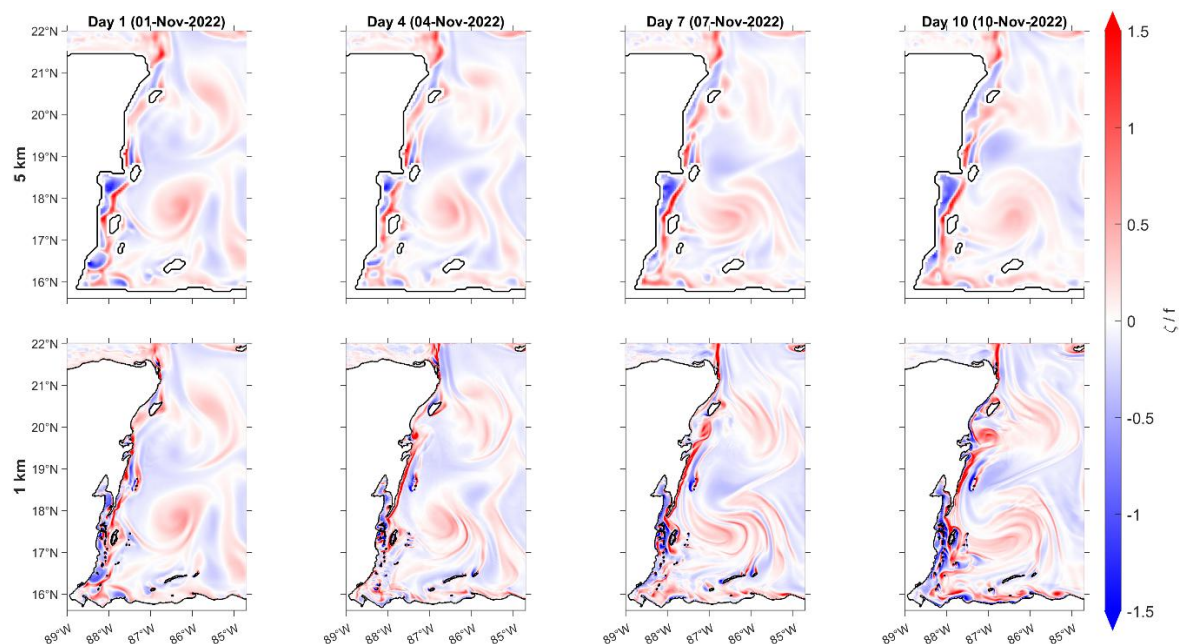


Fig. B2: Daily-mean Rossby number (ζ / f) fields calculated from surface ocean currents simulated with ROMS configured at 5 km (upper panels) and 1 km (lower panels) horizontal resolution. The panels show the daily mean fields for the Tropical Cyclone (1–11 November 2022) case on simulation days 1, 4, 7, and 10.

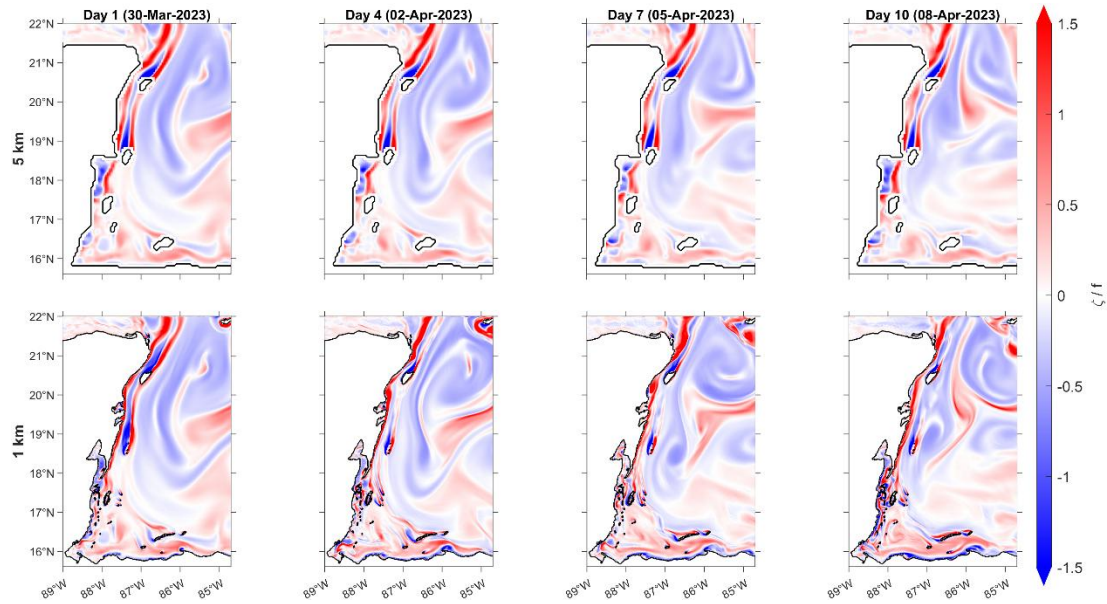


Fig. B3: Daily-mean Rossby number (ζ / f) fields calculated from surface ocean currents simulated with ROMS configured at 5 km (upper panels) and 1 km (lower panels) horizontal resolution. The panels show the daily mean fields for the Large Ro (30 March–9 April 2023) case on simulation days 1, 4, 7, and 10.

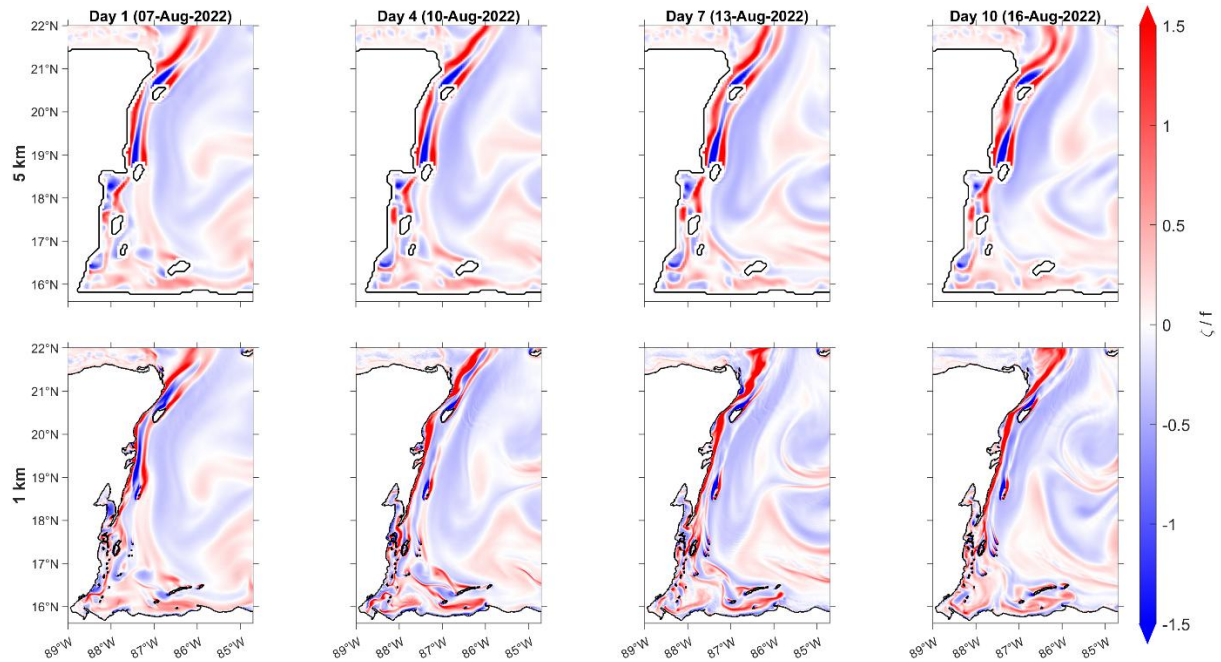


Fig. B4: Daily-mean Rossby number (ζ / f) fields calculated from surface ocean currents simulated with ROMS configured at 5 km (upper panels) and 1 km (lower panels) horizontal resolution. The panels show the daily mean fields for the Anticyclonic Eddy (10–20 June 2023) case on simulation days 1, 4, 7, and 10.

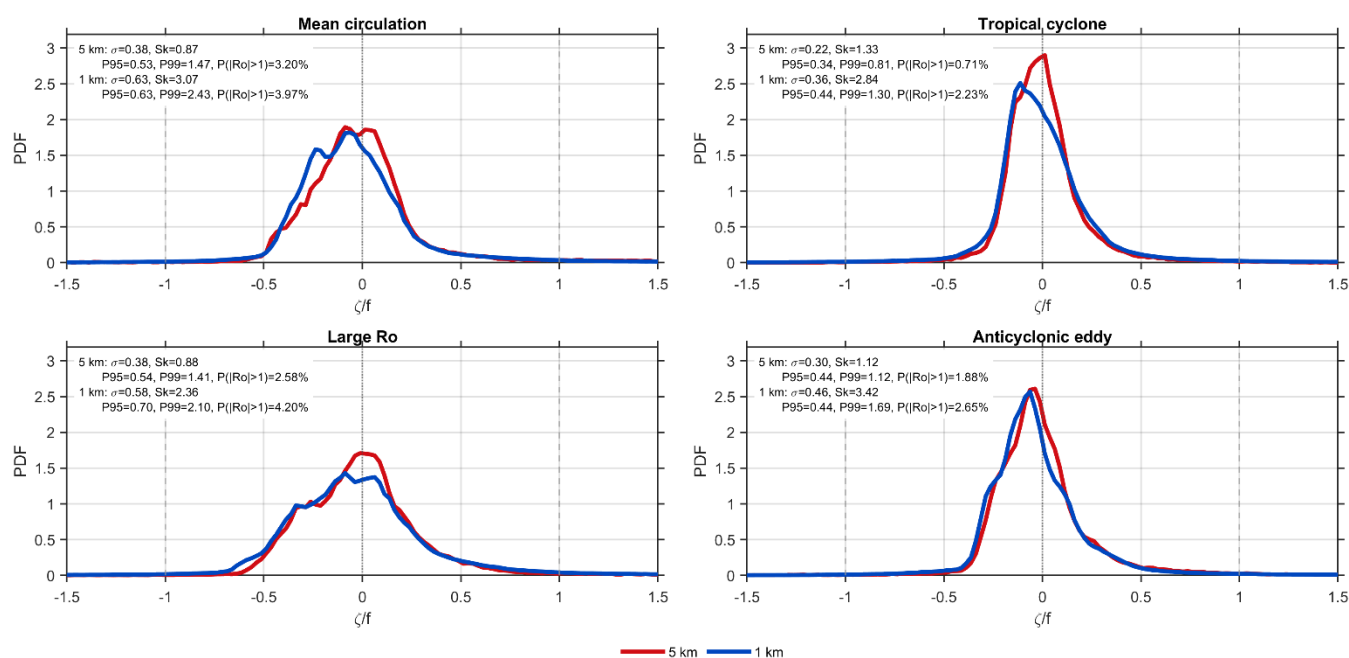


Fig. B5: Mean of the independently normalized daily probability density functions (PDFs) of the Rossby number ($Ro = \zeta/f$), calculated from daily-mean surface ocean current fields from the 5-km (red) and 1-km (blue) ROMS configurations. PDFs are shown for the four study cases: Mean circulation, Tropical cyclone, Large Ro, and Anticyclonic eddy. Each panel reports the standard deviation (σ), skewness (Sk), 95th percentile (P95), 99th percentile (P99), and probability of $|Ro| > 1$ for each configuration.

Response to Major Comment #4: Following our response to Major Comment #3, we have decided to eliminate attributions of the differences between model configurations to submesoscale processes, as we agree that the temporal resolution of the ocean currents is unlikely to represent all of these processes. Nevertheless, we included additional diagnostics of Rossby number fields as an Appendix (Appendix B), to show enhanced vorticity generation and greater positive skewness in the Rossby number distributions for the 1-km configuration compared to the 5-km one. The revisions regarding the interpretation of submesoscale effects and the additional diagnostics are the same as those described in our response to Major Comment #3.

We thank you for the references provided regarding the role of ocean currents and eddies in Sargassum transport and aggregation. We have consulted them and we agree that they provide relevant support for the following statements in the Introduction (please note that the sentence in lines 49-51 had already been modified in response to Referee #1):

Lines 41-43: “The size, distribution, and transport of Sargassum rafts are influenced by both biological growth processes and oceanic and atmospheric dynamics (Brooks et al., 2018; Marsh et al., 2021; Putman et al., 2020; Skliris et al., 2022; Uribe-Martinez et al., 2022; Zhang et al., 2024).”

Lines 49-51: “Mesoscale eddies have been shown to modulate Sargassum accumulation and redistribution across the tropical Atlantic by altering particle residence, aggregation, and downstream transport (Andrade-Canto et al., 2022; Beron-Vera et al., 2022; Brooks et al., 2019; Sosa-Gutierrez et al., 2025; Zhang et al., 2025).”

Accordingly, the following references were inserted in the References section (line 775):

Zhang, Y., Barnes, B. B., McGillicuddy, D. J., Jr., and Hu, C.: Sargassum enrichment in mesoscale eddies of the Great Atlantic Sargassum Belt, *Geophys. Res. Lett.*, 52, e2025GL114601, <https://doi.org/10.1029/2025GL114601>, 2025.

Zhang, Y., Hu, C., McGillicuddy, D. J., Barnes, B. B., Liu, Y., Kourafalou, V. H., Zhang, S., and Hernandez, F. J.: Pelagic Sargassum in the Gulf of Mexico driven by ocean currents and eddies, *Harmful Algae*, 132, 102566, <https://doi.org/10.1016/j.hal.2023.102566>, 2024.

Response to Major Comment #5: We agree that the definition of particle stranding and the release strategy require further clarification and that the limitations associated with both should be explicitly acknowledged. Regarding the stranding criterion, we recognize that crossing the 50-m isobath is not equivalent to actual Sargassum beaching. In our simulations, this criterion was adopted as a numerical proxy for particle arrival in nearshore waters, rather than as a representation of direct coastline contact. We acknowledge that this approach does not resolve the physical processes governing the final transport of Sargassum toward the shoreline and its subsequent beaching.

Regarding the release strategy, particles were uniformly distributed along 85°W, extending from 16° to 22°N, to represent an idealized population entering the study area from the Caribbean Sea and to provide a consistent initial particle distribution for comparing transport between the two ROMS configurations. However, we agree that this strategy does not reproduce the heterogeneous spatial distribution of real Sargassum rafts or their biomass. Therefore, we have clarified that the simulations are intended to assess differences in potential particle transport and nearshore arrival under the selected environmental conditions and numerical configurations, rather than to provide quantitative estimates of Sargassum biomass or actual beaching probability.

Based on this comment, we have revised the Methods and Discussion sections as follows:

Lines 183-187: “To analyse particle transport and nearshore arrival distributions in each of the four cases, 9,000 particles were released every 6 h for 10 days along a line at 85°W, extending from 16° to 22°N. This release configuration was designed to represent an idealized population of particles entering the study area from the Caribbean Sea and to provide a consistent initial distribution for comparing particle transport between the two model configurations. The uniform release strategy does not represent the heterogeneous spatial distribution or biomass of real Sargassum rafts. Rather, it allows us to assess differences in potential transport pathways and nearshore arrival patterns under the selected environmental conditions. Ocean currents were updated daily and wind fields were updated hourly. Particle trajectories were computed using a fourth-order Runge-Kutta integration scheme with a 300 s time step, and outputs were generated every 6 h.”

Lines 190-191: “...model domain. A particle was considered numerically stranded and was immediately deactivated upon crossing the 50-m isobath. This criterion was adopted as a proxy for particle arrival in nearshore waters rather than as an indication of actual coastline contact or Sargassum beaching. The 50-m isobath provides a defined nearshore threshold for comparing particle transport between the two configurations, while avoiding the assumption that the model resolves the processes governing the final approach of Sargassum to the shoreline. Consequently, simulated strandings (hereafter also referred to

as particle landings) should be interpreted as potential nearshore arrivals rather than actual beaching events. The percentage of particles in each category was calculated for comparison between resolutions.”

Lines 221-222: “...configurations. To determine the time required for particles to reach the prescribed nearshore threshold, we calculated the mean stranding time (days from release to crossing the 50-m isobath) for each 1/4° grid cell and case.”

Inserted on line 495: “A limitation of this study is associated with the adopted particle release strategy and stranding criterion. The uniform release of particles along 85°W provides a consistent initial distribution for comparing transport between the two model configurations but does not reproduce the heterogeneous distribution or biomass of real Sargassum rafts. Furthermore, the 50-m isobath is used as a numerical proxy for nearshore arrival rather than actual beaching. The simulated stranding percentages and arrival times therefore describe the transport of the prescribed particle population toward nearshore waters and should not be interpreted as direct estimates of Sargassum biomass, beaching probability, or the timing of actual beaching events.”

Response to Major Comment #6: We agree that the differences in Liu–Weisberg skill scores between the two model configurations represent an important result that deserves further discussion in the main text. As shown in Appendix A, the 5-km configuration generally produced higher mean Liu–Weisberg skill scores than the 1-km configuration when compared with the trajectories of the selected undrogued drifters. This indicates that the additional spatial detail represented by the 1-km configuration did not necessarily improve the agreement between simulated and observed drifter trajectories.

We acknowledge that this finding is relevant to the interpretation of our main results, particularly because differences in simulated particle transport between the two configurations should not automatically be interpreted as improvements in predictive accuracy. However, the drifter comparison was conducted using five undrogued drifters and 24-hour particle advection experiments and therefore does not provide a direct assessment of the accuracy of the simulated Sargassum strandings over the four 10-day case studies.

Accordingly, we have modified Appendix A and expanded the Discussion to explicitly address this result and its implications. We have also revised the conclusions to distinguish the additional spatial detail provided by the 1-km configuration from demonstrated improvements in the accuracy of Sargassum stranding predictions. We made the following modifications:

Inserted on line 397: “The comparison with undrogued drifter observations presented in Appendix A provides additional context for interpreting the differences between the two model configurations. The 5-km configuration generally produced higher mean Liu–Weisberg skill scores than the 1-km configuration, indicating better agreement with the observed drifter trajectories for the selected comparisons. This result suggests that the additional spatial detail represented by the 1-km configuration does not necessarily translate into more accurate particle trajectories. However, the drifter comparison was based on five undrogued drifters and 24-hour particle advection experiments and does not constitute a direct validation of the simulated Sargassum strandings. Consequently, differences between the two configurations should be interpreted as differences in simulated particle transport rather than as evidence that either configuration provides more accurate Sargassum beaching predictions.”

Lines 511-517: “Our results suggest that for operational and short-term forecasting purposes, using models with a 5 km spatial resolution may be sufficient to represent the general distribution and timing of Sargassum strandings in the region, under the limitations of the conditions represented by the four case studies, and the transport model and particle characterization employed in this study. However, in areas with high geomorphological complexity or during extreme events, the 1-km configuration can provide additional spatial detail and different simulated stranding patterns, although these differences do not necessarily imply improved predictive accuracy. Additionally, a detailed representation of the coastline is essential in simulations, as it directly influences stranding patterns.”

Lines 547-550: “The mean Liu-Weisberg skill score results (Fig. A1f) indicate that particle trajectories simulated using the 5-km configuration generally exhibit smaller separation from the observed buoy trajectories than those obtained using the 1-km configuration. This result shows that the additional spatial detail represented by the 1-km configuration did not necessarily improve trajectory agreement with the selected drifter observations. For each model configuration, the maximum skill score was identified as a function of the windage factor, and a value of 2.5% was selected for the Sargassum simulations because it yielded near-maximum skill scores for both configurations. Nevertheless, these comparisons assess the reproduction of undrogued drifter trajectories rather than directly validating the simulated Sargassum transport or stranding predictions.”

Replies to Minor Comments

Response to Minor Comment #1: We agree that the terminology used throughout the manuscript should more clearly distinguish simulated particle strandings from actual Sargassum beaching events. As clarified in our response to Major Comment 5, particles are considered numerically stranded when they cross the 50-m isobath, which is used as a proxy for nearshore arrival rather than actual coastline contact. Therefore, we revised the terminology throughout the manuscript to distinguish simulated particle strandings from actual Sargassum beaching. Where the term “particle landing” is retained, it refers specifically to the same numerical stranding criterion.

Lines 190-191: “...model domain. A particle was considered numerically stranded and was immediately deactivated upon crossing the 50-m isobath. This criterion was adopted as a proxy for particle arrival in nearshore waters rather than as an indication of actual coastline contact or Sargassum beaching. The 50-m isobath provides a defined nearshore threshold for comparing particle transport between the two configurations, while avoiding the assumption that the model resolves the processes governing the final approach of Sargassum to the shoreline. Consequently, simulated strandings (hereafter also referred to as particle landings) should be interpreted as potential nearshore arrivals rather than actual beaching events. The percentage of particles in each category was calculated for comparison between resolutions.”

Response to Minor Comment #2: When we refer to 1- and 5-km resolution we refer to nominal grid spacing. To be clearer about this distinction, we have revised the Abstract (Lines 9-11):

“Here, we compare how Regional Ocean Modeling System (ROMS) model configurations with horizontal resolutions of 5 km and 1 km (nominal grid spacing) modulate Lagrangian particle trajectories and subsequent coastal strandings.”

We also applied the following modifications in the Methods section:

Line 137: “The larger domain (Fig. 1, left panel), with a 5-km horizontal resolution (nominal grid spacing), extends from 15.6° to 30.5°N...”

Line 140-141: “The smaller domain (Fig. 1, right panel), with a 1-km horizontal resolution (nominal grid spacing), covers the area from 15.6° to 22°N and from 84.5° to 89°W.”

Response to Minor Comment #3: We agree that the original case-study description was overly qualitative, particularly for the Mean Circulation and Large Ro cases, and that a quantitative characterization provides a clearer basis for their selection. Following the reviewer’s suggestion, we have revised Section 2.1 to provide a more complete description of each of the cases and added a new table to Section 2.1 summarizing the atmospheric and oceanic characteristics of each case. The atmospheric diagnostics include the mean ERA5 zonal and meridional 10-m wind components, mean wind-speed magnitude and standard deviation, maximum wind speed, and circular-mean meteorological wind direction. The oceanic diagnostics include domain-mean surface-current speed, mean Yucatan Channel current speed, Cayman Current core position and speed, Rossby-number statistics, and domain-mean eddy kinetic energy (EKE) for both ROMS configurations. Section 2.1 was modified as follows:

2.1 Case study description

To assess differences in particle transport between the two ROMS configurations under contrasting environmental conditions, four 10-day case studies were selected. The cases represent background circulation, tropical-cyclone forcing, enhanced relative vorticity, and coherent anticyclonic circulation. To provide a quantitative characterization of these periods, Table 1 summarizes atmospheric and oceanic conditions, including ERA5 10-m wind characteristics, surface-current speed, regional current properties, Rossby number statistics, and eddy kinetic energy (EKE).

Atmospheric characteristics were calculated from the ERA5 zonal and meridional 10-m wind components over the study region. For each case, the domain- and time-mean zonal and meridional wind components, mean wind-speed magnitude, standard deviation, maximum wind speed, and mean wind direction were calculated. Mean wind direction was obtained as a circular mean using the meteorological convention, i.e. the direction from which the wind blows, measured clockwise from north.

Surface-current characteristics were calculated for both ROMS configurations. In addition to domain-mean current speed, we calculated the mean surface-current speed within the Yucatan Channel (21–22°N, 85–86.8°W). The Cayman Current was characterized following Carrillo et al. (2015), who determined the latitude of its core by searching for the maximum east–west current within 16–20°N and 84–88°W. Because the eastern boundary of the 1-km configuration is 84.5°W, we restricted the search to the common region 16–20°N and 84.5–88°W for both configurations. Within this common region, the Cayman Current core was defined as the location of the strongest westward case-mean zonal velocity, and its geographic position and total current-speed magnitude were recorded. Domain-mean EKE was calculated as $0.5(u'^2 + v'^2)$, where u' and v' are velocity anomalies relative to the case-mean surface flow. Rossby number statistics were calculated and described in Appendix B.

The first case (Mean Circulation; 7–17 August 2022) was selected to represent background circulation conditions in the absence of a tropical cyclone or a targeted coherent mesoscale eddy. Mean zonal and meridional winds during this period were -4.35 and 0.08 m/s, respectively, corresponding to predominantly easterly winds with a mean meteorological direction of 91.1°. Mean wind speed was 4.64

± 2.06 m/s, with a maximum of 13.19 m/s. Domain-mean surface-current speeds were 0.380 and 0.420 m/s in the 5-km and 1-km configurations, respectively, while mean Yucatan Channel speeds were 0.685 and 0.774 m/s.

To quantitatively evaluate whether the Mean Circulation period reflects the background ocean circulation, its current characteristics were compared with statistics calculated over the full available simulation period through 27 July 2023, after restricting both configurations to the common study region (15.6–22°N, 84.5–89°W). Full-period domain-mean surface-current speeds were 0.370 and 0.486 m/s in the 5-km and 1-km configurations, respectively. Thus, the Mean Circulation values differed from the full-period means by +2.5% and –13.6%, respectively. Full-period mean Yucatan Channel speeds were 0.596 and 0.780 m/s, compared with 0.685 and 0.774 m/s during the selected case.

The Cayman Current also followed a broadly similar pathway during the Mean Circulation case. The strongest westward flow within the common Cayman Current search region occurred at 18.09°N, 84.50°W in the 5-km configuration and 18.09°N, 84.52°W in the 1-km configuration, with current-speed magnitudes of 0.657 and 0.625 m/s, respectively. Over the full simulation period, the corresponding locations were 17.90°N, 84.65°W and 17.66°N, 84.52°W, with speeds of 0.419 and 0.557 m/s, respectively. Although regional current intensities do not exactly reproduce their full-period means, these comparisons show that the selected period provides a background-circulation example with large-scale current magnitudes and Cayman Current position broadly comparable to the longer-term circulation. We therefore use “Mean Circulation” as a descriptive case label rather than implying that this 10-day period is statistically representative of the complete simulation period.

The second case (Tropical Cyclone; 1–11 November 2022) encompasses the passage of Tropical Cyclone Lisa and was selected to investigate particle transport during an extreme atmospheric-forcing event. Mean zonal and meridional winds were -2.63 and -1.47 m/s, respectively, with a mean meteorological wind direction of 55.9°. The 10-day domain-mean wind speed was 4.65 ± 2.37 m/s, while the maximum wind speed reached 16.52 m/s, the largest among the four cases, reflecting the transient nature of the cyclone forcing. Domain-mean surface-current speeds were 0.283 and 0.271 m/s in the 5-km and 1-km configurations, respectively, and mean Yucatan Channel speeds were 0.451 and 0.433 m/s. The Cayman Current core occurred at 18.37°N, 86.45°W and 18.27°N, 86.49°W, with current-speed magnitudes of 0.470 and 0.463 m/s, respectively.

The third case (Large Ro; 30 March–9 April 2023) was selected to represent conditions of enhanced relative vorticity associated with intensified cyclonic circulation south of the Cayman Current. Mean zonal and meridional winds were -5.68 and 0.59 m/s, respectively, corresponding to a mean meteorological wind direction of 95.2°. Mean wind speed was 6.06 ± 2.31 m/s, with a maximum of 13.43 m/s. The 95th percentile of Ro was 0.54 and 0.70 in the 5-km and 1-km configurations, respectively, the largest P95 values among the four selected cases. The mean daily probability of $|\text{Ro}| > 1$ was 2.58% and 4.20%, respectively; the 1-km value was the largest among the four 1-km cases. The Large Ro case also exhibited the largest domain-mean EKE among the four periods, with values of 0.0163 and 0.0222 m^2/s^2 , and the largest mean Yucatan Channel current speeds, 0.786 and 0.803 m/s. The Cayman Current core occurred at 19.98°N, 85.20°W and 19.82°N, 85.37°W, with current-speed magnitudes of 0.658 and 0.815 m/s, respectively. Thus, the Large Ro case is defined primarily by its enhanced relative-vorticity and energetic-circulation characteristics.

The fourth case (Anticyclonic Eddy; 10–20 June 2023) was selected based on the presence of a coherent anticyclonic eddy south of Cuba. Mean zonal and meridional winds were -5.34 and 2.17 m/s, respectively, corresponding to a mean meteorological wind direction of 112.4°. Mean wind speed was 6.12 ± 2.34 m/s, with a maximum of 13.02 m/s. Domain-mean surface-current speeds were 0.442 and 0.464 m/s in the 5-km and 1-km configurations, respectively, while mean Yucatan Channel speeds were 0.674 and 0.683 m/s. The Cayman Current core occurred at 17.66°N, 85.35°W and 17.66°N, 85.38°W, with corresponding current-speed magnitudes of 0.581 and 0.564 m/s. Domain-mean EKE was 0.0095 and 0.0111 m²/s². This case was therefore defined primarily by the presence and spatial organization of the anticyclonic circulation south of Cuba.

Collectively, the four periods provide examples of contrasting atmospheric and oceanic conditions, including background circulation, transient extreme atmospheric forcing, enhanced relative vorticity, and coherent anticyclonic circulation. They were selected as case studies of these contrasting regimes rather than as statistically representative samples of all occurrences of the respective conditions over the simulation period. All of the cases represent atmospheric and circulation regimes that prevail in the study region; thus, evaluating Sargassum transport considering each case is relevant.

Case/Parameter	Mean Circulation	Tropical Cyclone	Large Ro	Anticyclonic Eddy
Mean zonal wind component (m/s)	-4.35	-2.63	-5.68	-5.34
Mean meridional wind component (m/s)	0.08	-1.47	0.59	2.17
Mean wind speed $\pm$ SD (m/s)	4.64 ± 2.06	4.65 ± 2.37	6.06 ± 2.31	6.12 ± 2.34
Maximum wind speed (m/s)	13.19	16.52	13.43	13.02
Mean wind direction	91.1°	55.9°	95.2°	112.4°
Mean current speed: Whole domain (m/s)	5-km: 0.380	5-km: 0.283	5-km: 0.429	5-km: 0.442
	1-km: 0.420	1-km: 0.271	1-km: 0.447	1-km: 0.464
Mean current speed: Yucatan Channel (m/s)	5-km: 0.685	5-km: 0.451	5-km: 0.786	5-km: 0.674
	1-km: 0.774	1-km: 0.433	1-km: 0.803	1-km: 0.683
Mean current speed: Cayman core (m/s)	5-km: 0.657	5-km: 0.470	5-km: 0.658	5-km: 0.581
	1-km: 0.625	1-km: 0.463	1-km: 0.815	1-km: 0.564

Cayman position	core	5-km: 18.09°N, 84.50°W	5-km: 18.37°N, 86.45°W	5-km: 19.98°N, 85.20°W	5-km: 17.66°N, 85.35°W
		1-km: 18.09°N, 84.52°W	1-km: 18.27°N, 86.49°W	1-km: 19.82°N, 85.37°W	1-km: 17.66°N, 85.38°W
Ro P95		5-km: 0.53	5-km: 0.34	5-km: 0.54	5-km: 0.44
		1-km: 0.63	1-km: 0.44	1-km: 0.70	1-km: 0.44
P(Ro >1) (%)		5-km: 3.20	5-km: 0.71	5-km: 2.58	5-km: 1.88
		1-km: 3.97	1-km: 2.23	1-km: 4.20	1-km: 2.65
EKE (m ² /s ²)		5-km: 0.0103	5-km: 0.0080	5-km: 0.0163	5-km: 0.0095
		1-km: 0.0146	1-km: 0.0114	1-km: 0.0222	1-km: 0.0111

Table 1. Quantitative characterization of the four 10-day study cases. Atmospheric statistics were calculated from ERA5 10-m winds over the study region. Mean wind direction is the circular-mean meteorological direction, expressed as the direction from which the wind blows and measured clockwise from north. Yucatan Channel values correspond to mean surface-current speed within 21–22°N and 85–86.8°W. Following Carrillo et al. (2015), the Cayman Current was characterized from the strongest westward case-mean zonal current within the common search region 16–20°N and 84.5–88°W; the table reports the total current-speed magnitude and geographic position at that point. EKE is the domain-mean eddy kinetic energy calculated from velocity anomalies relative to the case-mean flow. Rossby-number statistics are derived from daily-mean currents as described in Appendix B.

Response to Minor Comment #4: Thank you for your comment. Tidal forcing was not included in the ROMS simulations. This choice was motivated by previous observations indicating that tides make a relatively small contribution to the dominant circulation variability in the Mexican Caribbean. Cetina et al. (2006), based on a year-long array of current measurements along the Mexican Caribbean coast, found that tidal currents explained only 3.3–12.9% of the variance of the principal velocity component across the sampled locations. Closer to the coast, Coronado et al. (2007) characterized Puerto Morelos as a microtidal environment and found that the mean lagoon circulation is primarily driven by wave-induced flow and modulated by low-frequency variability associated with the Yucatan Current, with tidal forcing playing an additional, comparatively minor role.

We acknowledge, however, that tides can contribute to high-frequency variability and modulate exchange through the reef-lagoon channels. In particular, Coronado et al. (2007) found a clear tidal contribution at suprainertial frequencies, while also noting that tidal currents were considerably smaller within the lagoon inlets and mainly modulated the dominant wave-driven flow. Therefore, the present simulations are intended to represent the dominant, lower-frequency circulation rather than tidal-phase variability in nearshore and channel flows. We have clarified the absence of tidal forcing in the Methods section:

Line 144: “...12 hours). Tidal forcing was not included in any of the configurations. Both...”

Response to Minor Comment #5: We agree that the omission of horizontal diffusion represents an additional limitation of the adopted particle transport model and that its potential influence should be discussed more carefully. In this study, particle advection was calculated using the surface ocean currents from the two ROMS configurations and the same ERA5 wind forcing, without including an explicit horizontal diffusive term. This approach was adopted to compare the advective transport represented by the two configurations under the same particle transport parameterization.

However, we acknowledge that the absence of horizontal diffusion may affect the simulated particle dispersion and nearshore arrival patterns, as unresolved turbulent motions can contribute to horizontal spreading. These effects may be particularly relevant in the coarser-resolution configuration, where a larger range of spatial variability remains unresolved. We have therefore revised the Methods and Discussion sections to acknowledge this limitation and clarify that our findings reflect particle transport under the adopted advection-based formulation. We also recognize that including horizontal diffusion and evaluating the sensitivity of the results to its parameterization would be an important direction for future research.

Methods:

Lines 192-193: “An explicit horizontal diffusive term was not included in the particle transport simulations, as the objective was to compare the advective transport represented by the two ROMS configurations under the same particle transport parameterization. However, this approach does not account for particle dispersion associated with unresolved turbulent motions, which may influence the simulated particle distributions and nearshore arrival patterns. This limitation may be particularly relevant for the coarser-resolution configuration, where a larger range of spatial variability remains unresolved.”

Inserted on line 495: “The omission of explicit horizontal diffusion represents an additional limitation of the particle transport simulations. Although using the same advection-based formulation allows differences between the two model configurations to be compared without introducing different stochastic diffusion parameterizations, unresolved turbulent dispersion may influence particle spreading and the resulting stranding distributions. This effect may be particularly important in the 5-km configuration, where a larger range of smaller-scale circulation variability remains unresolved. Consequently, the simulated differences in particle transport and strandings may depend on the treatment of horizontal diffusion. Future research should assess the sensitivity of these results to the inclusion of horizontal diffusion and to the choice of diffusivity parameterization in each model configuration.”

Response to Minor Comment #6: We clarify that the particles are deactivated immediately after crossing the 50-m isobath. We have revised the Methods section accordingly (Lines 190-191):

“A particle was considered numerically stranded and was immediately deactivated upon crossing the 50-m isobath.”

Response to Minor Comment #7: We agree that relating particle landings to Sargassum biomass estimates is misleading given the particle characteristics and the limitations of the employed transport model. Therefore, we have applied the following modifications to the Discussion (Lines 474-475):

“This suggests that employing a more realistic shoreline representation could improve particle stranding predictions.”

And to the Conclusions (Lines 511-517):

“Our results suggest that for operational and short-term forecasting purposes, using models with a 5 km spatial resolution may be sufficient to represent the general distribution and timing of Sargassum strandings in the region, under the limitations of the conditions represented by the four case studies, and the transport model and particle characterization employed in this study. However, in areas with high geomorphological complexity or during extreme events, the 1-km configuration can provide additional spatial detail and different simulated stranding patterns, although these differences do not necessarily imply improved predictive accuracy. Additionally, a detailed representation of the coastline is essential in simulations, as it directly influences stranding patterns.”

Response to Minor Comment #8: In relation to our response to Major Comments #3 and #4, we have clarified that the currents are updated daily and have revised the manuscript to eliminate any attribution to submesoscale processes, as this may not be represented given the ocean current temporal resolution. Instead, we have added Rossby number diagnostics to show the enhanced relative vorticity in the 1-km configuration compared to the 5-km. The corresponding revisions were stated in Major Comment 3.

Response to Minor Comment #9: We agree that our original interpretation of the stranding locations based on the FTLE fields was not sufficiently supported by the theoretical framework of the FTLE methodology. We have therefore revised our interpretation of the FTLE results throughout the manuscript. In particular, we have carefully removed our previous interpretations of the FTLE fields as directly indicating attracting or repelling structures and transport pathways. As pointed out by Referee #1, the FTLE methodology alone does not allow for the identification of attracting or repelling Lagrangian structures or transport pathways, as their identification requires additional analyses. We agree with this observation and have revised the manuscript accordingly. We also agree that particle landing depends not only on the flow structures but also on coastal geometry, particle forcing, and the stranding criterion. We have therefore clarified this point in the revised manuscript and have avoided attributing the observed stranding locations solely to the FTLE patterns. We have modified subsection 2.2:

2.2 Finite-time Lyapunov exponents (FTLE) fields

To compare the finite-time deformation experienced by neighbouring particle trajectories under the 5-km and 1-km configurations, forward- and backward-time finite-time Lyapunov exponent (FTLE) fields were calculated. In this study, FTLE is used as a diagnostic of finite-time trajectory stretching rather than as a direct measure of particle transport, accumulation, retention, or stranding. To construct the FTLE fields, 339×229 particles were released on a uniform grid with 2 km spacing covering the entire study area. Particles were advected using surface currents and a windage factor of 2.5%, and a free-slip boundary condition was applied at the coast to ensure continuous FTLE fields.

Forward and backward FTLE fields were computed for each case by seeding particles on the regular grid and advecting them for 10 days using a time step of 300 s. For the forward simulations, particles were initialized on the first day of each case and integrated forward in time for 10 days. Conversely, for the backward simulations, particles were initialized on the last day of each case and integrated backward in time for 10 days.

FTLE quantifies the maximum finite-time stretching of initially neighbouring trajectories (Peng et al., 2024). To compute these rates, particles are initially distributed on a uniform grid with positions X_0 at time t_0 . The particles are then advected over a time T , and the resulting deformation of fluid parcels is quantified using the Cauchy-Green strain tensor. The FTLE at each point is derived from the largest eigenvalue of this tensor, following the formulation of Haller (2001):

$$\sigma_{t_0}^T = \frac{1}{|T|} \ln(\lambda_{max})$$

Where $\sigma_{t_0}^T$ is the FTLE, λ_{max} is the maximum eigenvalue of the Cauchy-Green strain tensor, and T is the integration interval. Ridges of forward-time FTLE are commonly interpreted as candidate repelling material structures, whereas ridges of backward-time FTLE may indicate candidate attracting material structures (Peng et al., 2024). However, FTLE ridges do not necessarily satisfy the variational or geodesic conditions defining objective Lagrangian coherent structures or material transport barriers (Haller, 2011; Haller, 2015; Haller and Beron-Vera, 2012). Accordingly, we use FTLE primarily to compare finite-time deformation patterns between model configurations.

We also modified section 3.1 as follows:

3.1 FTLE

To compare finite-time deformation patterns between the 5- and 1-km configurations, forward and backward FTLE fields were analysed for each case. In the Mean Circulation case, bands of elevated forward-time FTLE occur along the northern edge of the Cayman/Yucatan Current in both configurations (Fig. 2a, 2b), indicating strong finite-time stretching of neighbouring trajectories. The 1-km field exhibits finer and more filamentary deformation patterns than the 5-km field. These elevated-FTLE regions are spatially aligned with the Cayman/Yucatan Current, while the particle simulations show dominant particle advection toward Cozumel. Both configurations also exhibit elevated forward-time FTLE extending from the southeastern part of the domain toward the Islas de la Bahía. In the Gulf of Honduras, FTLE values are generally lower, although numerous filamentary deformation features are present. In the 5-km configuration, an additional band of elevated FTLE extends from the Cayman Current toward Xcalak; this feature is less pronounced in the 1-km configuration.

Backward-time FTLE fields exhibit pronounced ridges around and north of Cozumel in both configurations (Fig. 2c, 2d). Such backward-time FTLE ridges indicate strong backward-time stretching and may be interpreted as candidate attracting material structures, although they do not by themselves demonstrate particle accumulation or retention. The 1-km field contains a curved, eddy-shaped FTLE ridge that is absent or less clearly defined in the 5-km field. Both configurations also exhibit numerous filamentary backward-time FTLE ridges in the Gulf of Honduras and around Banco Chinchorro, indicating spatially complex finite-time deformation in these regions.

In the Tropical Cyclone case, forward-time FTLE fields exhibit a more spatially fragmented deformation pattern in both configurations (Fig. 2e, 2f), with numerous filamentary regions of enhanced stretching. These features are finer and more numerous in the 1-km configuration. In the 5-km field, a high-FTLE filament extends toward Cancun, whereas the corresponding feature is weaker in the 1-km field. A similar difference occurs east of Xcalak.

Backward-time FTLE fields exhibit a dipole-like deformation pattern in both configurations (Fig. 2g, 2h), more clearly defined in the 5-km field. In the 5-km configuration, an elongated backward-time FTLE ridge extends from Cozumel toward the Gulf of Mexico and subsequently westward along the northern Yucatan coast, whereas in the 1-km configuration the corresponding ridge extends northward without the same westward curvature. Additional backward-time FTLE ridges occur near Xcalak, the Islas de la Bahía, the Gulf of Honduras, and Cuba.

In the Large Ro case, forward FTLE fields exhibit high values along the northern edge of the Cayman Current towards Cozumel in both grids (Fig. 2i, 2j). These values are higher in the 5-km grid than in the 1-km grid, and in the 5-km grid the Cayman Current shows numerous filaments and instabilities. South of Cuba, high-value filaments are observed in both grids; these are more pronounced in the 1-km grid, which may indicate circulation around Cuba. In both grids, filaments originate southeast of the Islas de la Bahía and extend towards the Turneffe islands. In the Gulf of Honduras, FTLE values are low in both grids, although numerous filaments are present. In the 5-km grid, some filamentary FTLE features show higher values than in the 1-km configuration and extend toward Banco Chinchorro and northward along the coast.

Backward FTLE fields display high values in both grids (Fig. 2k, 2l) within the Gulf of Honduras, associated with filaments originating from the Islas de la Bahía and reaching the coasts south of Xcalak. High-value filaments also emerge from Banco Chinchorro towards the north in both grids. From Cozumel, high values extend towards the Gulf of Mexico; in the 1-km grid, these filaments reach westward along the northern coast of the Yucatan Peninsula. High FTLE values are also observed in the Yucatan Channel in both grids. South of Cuba, high-value filaments appear in both grids, likely induced by the presence of eddies.

In the Anticyclonic Eddy case, forward FTLE fields in both grids (Fig. 2m, 2n) exhibit maxima along the boundary of the anticyclonic eddy located south of Cuba, indicating enhanced finite-time stretching around the eddy. Elevated FTLE values also occur along the Cayman/Yucatan Current. Independently, particle simulations show substantial particle advection toward Cozumel. Elevated forward-time FTLE is also observed southeast of the Islas de la Bahía, while values in the Gulf of Honduras are generally lower and more filamentary.

Backward FTLE fields reveal high values around and north of Cozumel in both grids (Fig. 2o, 2p). Elevated backward-time FTLE also occurs around and north of Banco Chinchorro, particularly in the 5-km configuration. These patterns indicate differences in finite-time deformation between the configurations.

Modifications made to the Discussion:

Lines 397-443: “The FTLE analysis provided a complementary description of the finite-time deformation experienced by neighbouring particle trajectories under the two model configurations. The OpenDrift simulations indicated that the Cayman and Yucatan Currents constitute the dominant particle-advection route through the study area, directing a substantial fraction of particles toward Cozumel. Bands of elevated forward-time FTLE were spatially aligned with these currents, indicating strong finite-time stretching adjacent to the dominant advective flow. Backward-time FTLE ridges occurred around and north of Cozumel, Banco Chinchorro, and within the Gulf of Honduras, indicating regions of enhanced backward-time stretching that may be regarded as candidate attracting material structures. We do not, however, interpret these FTLE features alone as evidence of particle accumulation, retention, transport barriers, or likely landing sites. These quantities were assessed from the OpenDrift particle distributions

and stranding diagnostics, while FTLE was used to provide dynamical context for the deformation of neighbouring trajectories.

Allende-Arandia et al. (2023) used climatological Lagrangian coherent structures (cLCSs) to characterize persistent transport organization from the tropical Atlantic toward the Caribbean Sea and Gulf of Mexico. Their analysis identified the Yucatan Current as a persistent feature organizing along-current transport while restricting cross-current exchange toward the Mexican coast, with this organization weakened when wind forcing was included. The cLCS framework used in that study differs from the FTLE diagnostic employed here, and we therefore do not interpret our forward-time FTLE ridges as material transport barriers. In the Mean Circulation, Large Ro, and Anticyclonic Eddy cases, elevated forward-time FTLE occurs along the Yucatan Current (Fig. 2a, b, i, j, m, n), indicating strong finite-time stretching in the vicinity of the current. The OpenDrift trajectories independently show dominant along-current advection, consistent with the importance of the Yucatan Current in organizing regional Sargassum transport. Likewise, in many other coastlines with boundary currents, the onshore transport of larvae depends on factors that debilitate or break the predominant alongshore flow (Harrison and Siegel, 2014) as well as on conditions that generate across shore flows such as onshore winds (Caputi et al., 2002) or eddies (Cetina-Heredia et al., 2019; Roughan et al., 2022).

During the Tropical Cyclone case, forward-time FTLE values are generally lower and the high-FTLE regions associated with the Cayman/Yucatan Current are less continuous than in the other cases (Fig. 2e, 2f). This indicates weaker or more spatially fragmented finite-time stretching over the selected 10-day interval, rather than necessarily weaker transport. The OpenDrift simulations independently show larger resolution-dependent differences in particle trajectories and strandings during this case. Thus, the altered FTLE geometry is interpreted as evidence of changes in trajectory deformation, while changes in particle transport are assessed directly from the particle simulations.

The largest differences in particle stranding between the model configurations occur during the Tropical Cyclone case. The Rossby-number analysis in Appendix B indicates enhanced small-scale vorticity and a greater occurrence of large Rossby numbers in the 1-km configuration. The particle simulations also display greater divergence between resolutions during this case, while the FTLE fields indicate corresponding differences in finite-time deformation. Collectively, these diagnostics suggest that short-term particle predictions become more sensitive to differences in the simulated ocean circulation under intense atmospheric forcing, potentially reflecting the combined influence of horizontal resolution and other differences between the model configurations.

The highest particle-landing percentages across the four cases occurred around Cozumel, Banco Chinchorro, the Sian Ka'an Reserve, and northern Cancun (Fig. 4). The FTLE fields exhibit regions of enhanced finite-time deformation around several of these locations, including backward-time FTLE ridges around Banco Chinchorro and north of Cozumel. These spatial correspondences provide complementary information on the deformation experienced by nearby trajectories, whereas the identification of landing hotspots is based directly on the OpenDrift stranding simulations."

Lines 460-469: "In Jouanno et al. (2025), the annual Sargassum biomass was estimated from 2018 to 2023; they reported that the coastline from Xcalak to Puerto Morelos receives approximately 100,000 tons of Sargassum biomass per year, the western Cuban coast receives about 40,000 tons, and the Islas de la Bahia receives less than 20,000 tons per year. In agreement, our results registered strandings along the coast from Xcalak to Puerto Morelos (Fig. 4), possibly associated with particle transport by the Yucatan

Current and its interaction with onshore winds. Our particle simulations also produce strandings along the Cuban coast and the Islas de la Bahía (Fig. 4). Around Cuba, these particle trajectories occur in a region characterized by mesoscale eddying circulation, while the FTLE fields show pronounced deformation around the corresponding eddy boundaries. The FTLE patterns alone do not establish eddy-driven retention or attraction, but their spatial correspondence with the particle trajectories is consistent with an influence of mesoscale circulation on particle redistribution. For the Islas de la Bahía, the simulated trajectories indicate direct transport from particles released south of the core of the Cayman Current.”

Modifications made to Conclusions:

Lines 503-509: “The highest stranding percentages were consistently observed around Cozumel, Banco Chinchorro, the Sian Ka’an Reserve, and the northern coast of Cancun, in agreement with previous observational and modelling studies (Chavez et al., 2020; Lara-Hernandez et al., 2024; Jouanno et al., 2025; Uribe-Martinez et al., 2022). Due to their exposure to prevailing currents and the orientation of the coastline, these regions are particularly vulnerable to massive Sargassum landings (Lara-Hernandez et al., 2024; Uribe-Martinez et al., 2022). The particle simulations identify recurrent advective routes associated with the Cayman and Yucatan Currents and show that mesoscale and coastal circulation features influence the spatial distribution of particles and landings. The FTLE fields provide complementary information on finite-time trajectory deformation in these regions.”

Response to Minor Comment #10: Thank you for the references provided. We have consulted them and decided that it is pertinent to include them and cite them to support said statement. Therefore, we have made the following modifications to the Introduction (Lines 68-69):

“Multidisciplinary efforts have been undertaken to develop Sargassum forecasting systems at basin and seasonal scales, mainly focused on the tropical Atlantic (Berline et al., 2020; Hu et al., 2016; Jouanno et al., 2021, 2023; Putman et al., 2025; Triñanes et al., 2021).”

And added to the References (note that the article by Hu et al. was already in the reference list):

Inserted in line 722: Putman, N. F., Beyea, R. T., Ackerman, E. G., Trinanes, J., Henaff, M. L., Hu, C., and Lumpkin, R.: Systems to monitor and forecast pelagic Sargassum inundation of coastal areas across the North Atlantic: present tools and future needs, *Harmful Algae*, 149, 102933, <https://doi.org/10.1016/j.hal.2025.102933>, 2025.

Inserted in line 761: Triñanes, J., Hu, C., Putman, N. F., Olascoaga, M. J., Beron-Vera, F. J., Zhang, S., and Goni, G. J.: An integrated observing effort for Sargassum monitoring and warning in the Caribbean Sea, tropical Atlantic, and Gulf of Mexico, in: *Frontiers in Ocean Observing: Documenting Ecosystems, Understanding Environmental Changes, Forecasting Hazards*, edited by: Kappel, E. S., Juniper, S. K., Seeyave, S., Smith, E., and Visbeck, M., *Oceanogr.*, 34, 68–69, <https://doi.org/10.5670/oceanog.2021.supplement.02-26>, 2021.

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