Response to Referee #2

Surface Kinetic Energy Distributions in the North and Equatorial Atlantic
Derived from Surface Drifter Observations and High-Resolution
Numerical Models with Tidal Forcing
now:
Surface Horizontal Kinetic Energy Sensitivity to Numerical Parameters
in Tidal-Resolving North and Equatorial Atlantic Simulations
Laxenaire et al., egusphere-2025-6355

This study provides a comprehensive analysis of surface horizontal kinetic energy (KE) levels using high-resolution numerical simulations of the North and Equatorial Atlantic Oceans. They compared the results of numerical drifter experiments with surface drifter observations and further KE estimates in the Lagrangian versus Eulerian framework. The most distinguished part of this manuscript from previous published studies, is the sensitivity tests to explore the impacts of the forcings (tidal & winds) and model parameters on KE estimates by numerical simulations. Overall, this paper is well written and clearly organized, and the findings are of significant interest, offering valuable insights to the modelling community.

I highly recommend this paper for publication in Geoscientific Model Development after addressing the following major concerns about the objectives, results and reasons for the discrepancies between observations, different framework, and various numerical simulations. And some minor corrections are also required to be done.

We thank Referee 2 for the careful reading of the manuscript and for the constructive comments. Like Referee 1, Referee 2 indicates that our findings are of significant interest but that the manuscript did not bring them forward as clearly as it could, both in the way the objectives and results are presented and in the discussion of the discrepancies between datasets. We have therefore undertaken a substantial restructuring effort, presenting our results more clearly and discussing them in greater depth, and we hope that the revised version now adequately addresses the reviewer's concerns. The result is a substantially modified manuscript that we hope now addresses the reviewer's remarks. The reviewer's comments are reproduced in bold below and our responses follow in normal text.

Major comments

1. Title alignment. The title does not convey the motivation and key findings of this paper. In both the abstract and most of the results section, the authors focus more on the numerical Lagrangian versus Eulerian analysis and on the sensitivity of the Eulerian simulation to the choices of parameters and forcings. The comparison between surface drifter observations and numerical simulations does not seem to be a central topic of this study. The authors should carefully reconsider the title.

We agree and have revised the title to "Surface Horizontal Kinetic Energy Sensitivity to Numerical Parameters in Tidal-Resolving North and Equatorial Atlantic Simulations". The new title makes it explicit that the sensitivity to numerical parameters is the core of the paper, and no longer suggests that the drifter comparison is the main topic. We have also adjusted the abstract to give the sensitivity-to-parameters message in the first sentence rather than the drifter comparison.

2. Manuscript structure and visualisation. The manuscript is long and repetitive. It would be easier to read if the authors combined the zonally averaged rotary spectra with the KE maps for each subsection, so that the texts and figures are next to each

other. The current figures are somewhat repetitive. The authors could consider using more diverse plots to present their results (e.g. Figure 5 in Arbic et al., 2022; Figure 4 and Figure 5d–f in Zhang et al., 2024).

First, we agree that the manuscript, and in particular the sensitivity-test sections, is repetitive both in text format and in figure layout. The mirroring of the sensitivity subsections across twin experiments is deliberate, as the goal is to provide directly comparable diagnostics for each parameter change. To make the paper easier to read, however, we have extended, at the end of each twin-experiment subsection, the paragraph that discusses the global effect of the parameter on each frequency band. We have also followed the reviewer's advice and combined the zonally averaged rotary spectra with the surface horizontal kinetic energy (SHKE) maps into a single figure per twin experiment, so that the full diagnostic for one sensitivity test now sits on a single page. Repeating the same layout across the figures of the twin experiments is also a deliberate choice that allows the reader to easily compare panels from one experiment to the next.

Second, regarding the diverse plots used by Arbic et al. (2022) and Zhang et al. (2024), these studies compared far fewer datasets than ours, which allowed them to dedicate one figure to each frequency band. Applied to our seven simulations together with the Lagrangian and drifter references, the same approach would substantially multiply the number of figures, which would make an already long paper even longer. We have preferred to introduce a new figure (Figure 11 in the revised manuscript - see below), which provides a cross-experiment visualisation in which each change between twin experiments is represented by a single panel showing the relative change in SHKE in each frequency band and in each subdomain. Figure 11 is now the backbone of the discussion in Section 6.

3. Drifter experiment design. Why did the authors choose observations from undrogued drifters? Why does the OP 1/2° experiment (Figure 1b) have less coverage in the northern part of the domain (say, 50°N and further north) than the undrogued drifter distribution (Figure 1c)? The distribution of trajectories in Figures 1b and 1c looks very different; in this case, does the comparison in Section 4.1 (Figures 3–4) make sense? Why not use OP Seed Drifters to compare with drifter observations directly? Section 4.2 and its figures may not be necessary or could be moved to the supplementary material.

These are three related questions and we address them in turn.

First, undrogued drifters are used because the SHKE we analyse is defined at the ocean surface, and undrogued drifters have been described as sampling surface velocities more accurately than drogued ones (Niiler and Paduan, 1995; Lumpkin and Pazos, 2007). This is, for example, why Arbic et al. (2022) compare surface and 15-m currents using undrogued and drogued drifters as reference, respectively. We have added a sentence stating this reasoning explicitly in the first paragraph of Section 2.1.

Second, the OP Seed 1/2° experiment does not extend beyond 65°N and below 15°S on purpose. These latitudinal restrictions were imposed to avoid proximity to the model open boundaries (located near 28°S and 80°N at the Fram Strait); the northern limit of 65°N also corresponds approximately to the Greenland-Scotland Ridge, which forms a natural boundary of the North Atlantic basin. We have added a sentence in Section 2.2 to make this choice and its justification explicit.

Third, we thank the reviewer for this suggestion, which we have adopted. In the revised paper, OP Seed Drifters is now the Lagrangian reference in both subsections of Section 4: it is compared to the undrogued drifters in Section 4.1 and to the Eulerian NEATL50-T-HB-HF field in Section 4.2. The comparison in Section 4.1 is therefore built on the same spatial distribution as

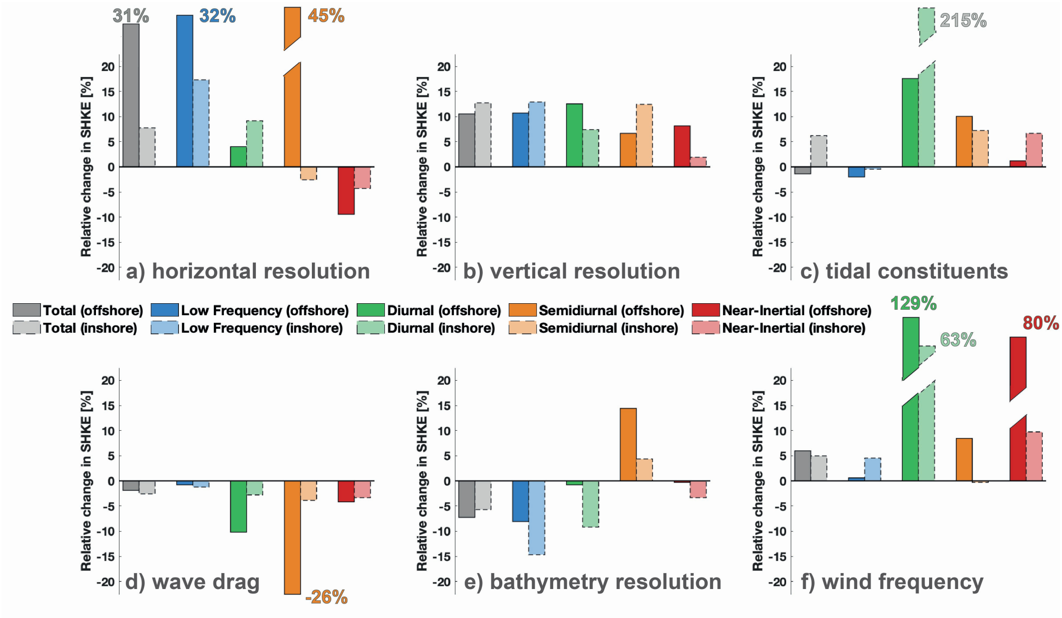

Figure 11: Sensitivity of the domain-averaged surface horizontal kinetic energy (SHKE) to six model configuration choices, separately for the offshore (waters deeper than 500 m; filled bars, solid edges) and continental shelf (waters shallower than 500 m; lighter bars, dashed edges) subdomains of the NEATL region. Each panel shows the relative change in SHKE, $(\mathrm{SHKE}_{\mathrm{mod}} - \mathrm{SHKE}_{\mathrm{ctrl}})/\mathrm{SHKE}_{\mathrm{ctrl}}$ (in %), induced by a single parameter modification, decomposed into five components: total SHKE (grey), low-frequency ($>$ -0.5 cpd and $<$ 0.5 cpd, blue), diurnal ($\pm$[0.9, 1.1] cpd, green), semidiurnal ($\pm$[1.9, 2.1] cpd, orange), and near-inertial ($\pm$[0.9, 1.1]f cpd restricted poleward of $\pm 5°$ latitude, red). The six parameter pairs (control to modified) are: (a) horizontal resolution, NEATL12-T to NEATL50-T; (b) vertical resolution, NEATL12-T to NEATL12-T-HVR; (c) number of tidal constituents, NEATL12-M_2 to NEATL12-T; (d) inclusion of internal wave drag, NEATL50-T to NEATL50-T-WD; (e) bathymetry resolution, NEATL50-T to NEATL50-T-HB; (f) atmospheric forcing temporal frequency, NEATL50-T-HB to NEATL50-T-HB-HF. The vertical axis is clipped at $\pm 20\%$ for readability; values outside this range are reported numerically above (positive) or below (negative) the corresponding bar.

the observations, and residual differences cannot be attributed to sampling density. The impact of OceanParcels sampling density itself (former Section 4.2 in the initial submission) is quantified separately in Supplementary Section S4, which compares OP Seed Drifters to OP Seed 1/2°.

4. Depth of discussion. Most of the results are a basic description of plots and comparisons. More discussion about the underlying reasons or mechanisms would be valuable. The Summary is also too long and repeats information from previous sections. It would be a good idea to make this section brief, leaving only key take-away messages, and to add a short paragraph at the end of the Summary with implications for using drifter observations and numerical Lagrangian versus Eulerian analysis of KE, and directions for future studies.

We agree and we have revised both the body sections and the summary/discussion section.

In the body of the paper, we have expanded the mechanistic discussion in Sections 5.1 (e.g., tidal vs non-tidal diurnal), 5.2 (e.g., near-inertial transfer to depth), 5.3 (e.g., role of the vertical grid in resolving horizontal flows), 5.4 (e.g., selective action of wave drag equatorward of critical latitudes), 5.5 (e.g., transfer from low-frequency to internal-tide generation over better-resolved topography), and 5.6 (e.g., resolved diurnal and semidiurnal wind cycles). Each subsection now closes with a paragraph that attempts to explain the diagnosed signal rather than only describing it.

Section 6 has been restructured into a discussion of per-band parameter sensitivity, built around Figure 11. Rather than restating each pair of experiment band by band as in the initial submission, the discussion now focuses on each frequency band in turn: it first recalls the model-drifter difference in that band after accounting for the Lagrangian distortion quantified in Section 4.2, then discusses the two or three parameters that most strongly affect the SHKE distribution there, and, where applicable, indicates how these parameters could be adjusted to reduce the model-drifter gap.

Minor comments

Table 2 and Table 3 show overlapping information. Keep only one in the main text; the other could be removed or placed in the supplementary material.

We have merged both tables into a single one (now Table 2 in the revised manuscript), which retains the absolute SHKE for the total signal together with the fractional SHKE per band. The full set of absolute SHKE values per band (previously Table 2 in the initial submission) has been moved to the supplementary material as Table S1. The main-text discussion is now organised in fractional terms, which is the quantity that carries the cross-dataset comparison, and the absolute values are available in Table S1 for reference. Note that, in Section 6, absolute values are provided again in a new form in Figure 11.

l. 243: this sentence refers to Yu et al. (2019)? Then Yu et al. 2019 should be put into brackets.

The citation has been corrected to the parenthesised form (Yu et al., 2019).

l. 266–267: repeating information "The bipolar pattern in the diurnal band, with more KE poleward of 30°N in the observations but equatorward in the model," has already been said at the beginning of l. 265. The authors should try to be concise when describing the results.

This duplicated description has been removed. The critical latitude is now introduced once, in the paragraph where Figure 3 is first discussed, and simply referenced without redescription in the later paragraphs of the section.

l. 270: "Once can . . . " → "One can . . . "?

Corrected, thank you.

There might be some other typos and minor errors throughout the text; the authors should carefully check and correct them.

The manuscript has been proofread again and we hope that the remaining typographical errors have been corrected.

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