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Interactive comment on "A Lagrangian study of the contribution of the Canary coastal upwelling to the open North Atlantic nitrogen budget" *by* Derara Hailegeorgis et al.

Anonymous Referee #1

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The paper by Hailegeorgis et al. examined upwelling and transport patterns in the Canary Current System using a Lagrangian modeling approach. The authors identified latitudinal variability in water and nitrogen export, determined transit time of water parcels from the coast to the oligotrophic oceanic region, examined the role of major capes as drivers of upwelling and offshore transport, and quantified the coastal upwelling contribution to the nitrogen stock in the North Atlantic Tropical Gyral and the North Atlantic Subtropical Gyral East. Overall, I think that the paper does an interesting contribution to the understanding of nitrogen export patterns in the Canary Current System. However, important changes need to be made in order to recommend publication.

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Discussion paper

My main concerns are two:

1) The paper is not easy reading:

There are a lot of results and figures with multiple panels and supplement figures, which made fuzzy the paper's main points. There is some redundancy in the reported results. Subregional patterns not always showed important differences, so not sure if you always need reporting all subregional results in the paper main body (you can move some Figure's panels to the Supplement).

The manuscript length could be reduced, trying a better integration of the paper results. Results and discussion were mixed, which did not help to get the present study contribution. I am not an English native speaker, but below (specific comments) I made a series of suggestions to help making sentences more concise and clear.

The authors need explaining much clearly how all the Lagrangian patterns were calculated in the Method section.

2) Model validation:

The authors need to include vertical sections and vertical profiles from the modeled variables and compare them with observations (WOA sections would be OK). I would like to see whether the vertical patterns in the model outputs have any significant bias. Is the nutricline depth consistent with observed patterns across the model domain? Is the model reproducing well the seasonal variability in vertical patterns? It is not enough the correlation analysis in Fig. 1 from the Supplement, since well-correlated variables can have important differences in terms of magnitude.

Since a correlation analysis per se does not show a potential bias in the simulated variables, besides the annual mean patterns shown in Fig. 2. I would like to see a comparison for mean seasonal patterns of SST and surface chlorophyll.

To reduce paper length, I recommend including the model validation as an independent section in the Supplement.

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Discussion paper

Specific comments:

Please, refer to the supplement figures as Figure S1, Figure S2, etc. It was confusing when a paper and supplement figures were mentioned at the same time. As example, instead of using (Fig. 7 and Fig. 8, SI), use (Fig. 7 and Fig. S8).

Abstract

Pag.1, L11: "Our model analysis suggests that the vast majority of the upwelled waters originate from offshore and below the euphotic zone (70m depth), and once upwelled remain in the top 100m". I understand what you mean, but the statement is not clear. Consider that you defined upwelling as a water parcel crossing the 70 m depth level.

Introduction

Pag.2, L13-14: The sentence "leading to substantial modifications of the biogeochemical cycles there" is ambiguous. You could delete it.

Pag.2, L20: delete "potentially"

Pag.2, L32: delete "potentially"

Pag.3, L10: "surface jet associated with the upwelling flowing equatorward" => "surface jet associated with the coastal upwelling front, which flows equatorward"

Pag.4, L6: "and therefore did not estimate" => "so did not estimate"

Pag.4, L8-10: These sentences need additional work. Explain better but concise.

Pag.4, L13: What do you mean with "quantify the reach"

Pag.4, L13: "the spatial structure and the dominant timescales"

Pag.4, L23-24: and quantifying the offshore export

Pag.4, L24: "We also investigate"

Methods

Pag.5, L2: Was bottom remineralization included in the model? This is a relevant source of nitrogen, which can largely influence inorganic nitrogen patterns on the shelf. If it was not considered, you should mention it as another limitation in the study.

Pag.5, L14-15: Did you use a monthly climatology for wind stress? If this is the case, vertical mixing was probably underestimated. Did you compare the simulated mixed layer depth with observations?

Pag.5, L17-18: It was mentioned that the model was spun up by 12 years, and the study was based in simulation years 10 to 12. So does it mean that you used the last 3 years of your model spin up for the analysis? If this is the case, you have to report that the model was spun up by 9 years.

Figures 1 and 2: I suggest including the 200 m isobath (shelf break) as a contour line on the maps.

Pag.9, L2: It is Figure 2 not 1.

Pag.9, L14: Indicate that vertical mixing is not considered in the Lagrangian analysis

Pag.9, L25: Since the dominant circulation pattern in the CanCS appears to be along-shore, I am wondering why only oceanic particles were considered in the Lagrangian experiment. I would expect that upwelled particles also come from the northern and southern boundaries. Could the poleward undercurrent be a source for upwelled waters?

Results

Pag.13 L7: "onshore-offshore contrast" => "cross-shore differences"

Pag.13 L9: "followed by a second one at around 50 km from the shore" => "and a secondary maximum around 50 km"

Pag.13, L20. Shallow regions should also show upwelling because a distance of 50 km from the shelf break was considered for the analysis. Right? Clarify.

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Discussion paper

Pag.13, L25: what is the range considered for the upwelling zonal integration in Figure 6a (same for Figure 5a).

Pag.13, L26-28: Wondering if the shallow nutricline is linked to the high-nutrient SACW or not.

Pag13, L28-29: "The central subregion has a moderate nitrogen flux associated with upwelling while the northern subregion has the weakest upwelling flux of nitrogen" => "The weakest upwelling-driven nitrogen flux was in the northern subregion"

Pag.13, L30: "disproportionately lower" => "much lower"

Pag.15: It is important to note that a water parcel released in region A can be upwelled in subregion B or C. Beside, a water parcel upwelled in region A can be transported away to region B or C. Consequently, the parcel transport not necessarily depends on the oceanographic conditions in region A. If I'm right, I suggest revisiting all sentences describing subregional offshore transport results. As example, I would modify "the offshore transport is fastest in the central subregion and slowest in the northern subregion" by "the particle upwelled in the central and northern subregions displayed the fastest and slowest offshore transport, respectively". Besides, I would change "At larger distances from the coast (beyond 400 km), the offshore transport becomes faster in the southern subregion" by "The fastest water parcels beyond 400 km from the coast are those upwelled in the southern subregion"

Pag.15, L3: define "transit time".

Pag.15, L15-16: Why is this maximum at 150 km? Does it mean that a greater fraction of water parcels remains around this distance? Is this linked to patterns in alongshore circulation?

Pag.15: L22: "This is because of its low offshore transport efficiency and the relatively low volume of upwelling" => ''Reduced coastal upwelling and low offshore transport efficiency explain this pattern."

Pag.15, L22: Define transport efficiency.

Table 2: It may be informative reporting the standard deviation for transit time.

Pag.16, L3-5: "At close to 150 km from the coast (corresponding to the edge of the coastal upwelling stripe), the offshore transport of nitrogen reaches its maximum, reaching values as large as 500 Gmol yr^{-1}. Thereafter, the offshore transport decreases exponentially" => "Around 150 km from the coast, the nitrogen transport reaches values as large as 500 Gmol yr-1 at 200 km, decreasing exponentially further offshore"

Pag.16, L7: "In spite of having the lowest offshore transport of water, the southern subregion exports the highest amount of nitrogen offshore at 200 km" => "Although offshore water transport was minima in the southern CanCS, this subregion has the greatest offshore export of nitrogen."

Pag.16, L9: "At larger distances from the coast, the situation reverses." => "This pattern reverses further offshore"

Pag.18, L2-4: I disagree with this statement: "so that beyond the nearshore 50 km region, inorganic nitrogen in the form of nitrate dominates the nitrogen pool at all distances from the coast". NO3 dominates almost everywhere, and its contribution to total nitrogen is actually much larger in the coastal region than in the oceanic region.

Pag.18, L21-34: It would be nice having a brief introductory explanation for the motivation of the analysis in this subsection. As example, evaluate the impact of subduction on transit time, impact of subduction on nutrient fluxes or nutrient cycling.

Pag.18, L21: "Upwelling particles that..." => "Upwelled particles that..."

Pag.18, L22: How do patterns in Fig. 8a,b from the supplement were calculated?

Pag.18, L24: I cannot see the secondary upwelling in the open ocean. Describe better.

Pag.18, L30: It is not evident for me why persistent filaments contribute to enhanced subduction. Explain.

Figure 9: I recommend include this figure in the Supplement.

Pag.20. Indicate what the positive/negative values in Fig. 10 represent

Pag.21. Indicate what the positive/negative values in Fig. 11 represent

Pag.22, L26: "offshore transport of upwelled particles"

Pag.22, L30: I am not sure whether remotely upwelled water is a good term. I would prefer describing the results in terms of local and non-local upwelling.

Pag. 22, L32: "water upwelled"

Pag. 23: L1: "Corresponding enhancement in local nitrogen upwelling and export is seen only in" => "Increased offshore transport of nitrogen due to increased local upwelling is seen only in"

Caption of Figure 12: "Transport by water upwelling locally" => "Transport associated with locally upwelled water"

"Transport by particles that leave the coastal upwelling region at each cape or non-cape area but upwell remotely" => "Transport associated with remotely upwelled water"

Pag.24, L1-2: "The offshore transport of nitrogen by remote upwelling exported by all capes constitutes more than 30% of the total offshore transport of upwelling" => "Remotely upwelled waters that are transported offshore around major capes represent more than 30% of the total transport"

Pag.24, L4-5: "In fact, all capes source the majority of water and nitrogen they export from remote upwelling (Table 3). All capes also source more of their export from remote upwelling compared to the rest of the coast." => "Indeed, most of the water and nitrogen exported offshore around major capes is non-locally upwelled (Table 3)"

Pag.27, L10: For consistency use CanCS

Pag.27, L21-29: I did not understand. Please, explain better how did you estimate the CanCS contribution to the NATR and NASE provinces.

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