Reply to:

Interactive comment on "Circulation of the European Northwest Shelf: A Lagrangian perspective" by Marcel Ricker and Emil V. Stanev

Anonymous Referee #2

Received and published: 24 January 2020

We thank reviewer #2 for the constructive review of our paper. We provide point-by-point answers in the attached pdf.

Summary

The authors have performed a set of Lagrangian particle tracking experiments to study the water circulation on the European Northwest Shelf (ENWS). Several scenarios were simulated, with particles (passive tracers, or water masses) released at surface and seafloor, and simulated forwards for up to 1 year, plus one case with backwards simulations. A property called "density trend" is defined to aid the analysis of the spatial accumulation of particles.

General comments

As the authors themselves point out, several modeling studies have looked at the ENWS, but not so many studies have applied Lagrangian methods, at least not for the whole area. The simulated scenarios are sensible, and the discussion contains several interesting comments and findings, though nothing groundbreaking. The main weakness of the paper is that the discussion would need a more clear structure, and be better linked to well defined motivation/objectives. But after improving the structure (i.e. major revision) and some details as discussed below, I would find this manuscript suitable for publication.

Authors: Thank you. We improved the structure (see also a comment below) of the paper and clarified the objectives of the respective experiments (line 188-196). The minor comments have been implemented as given below. Note that the quantity "density trend (DT)" has been renamed to "normalised cumulative particle density (NCPD)".

Specific comments

Line 29: Missing end parenthesis.

Authors: Added.

Lines 40-50 discusses typical current patterns. It would be helpful with a figure with arrows to better follow this description.

Authors: We added schematically grey arrows in Fig. 1 to indicate the general shelf sea circulation (line 42-43). To complement this, we added "Howarth (2001)" (line 52-53) as a reference for North Sea circulation.

Line 50: Could ref to Fig2c for the comment about low salinity along coast.

Authors: To improve the structure, we want to prevent mixing up the order of the figures appearances. However, Fig. 2d is mentioned in Sect. 2.3 with respect to the low salinity along the coasts.

Lines 50-52: This major hypothesis should be reflected also in abstract.

Authors: Done as suggested (line 24).

Lines 60-62: Sentence is a bit hard to read.

Authors: Improved (line 65).

Line 75: Should mention here that vertical mixing is also not considered. This is an important point, that should also be discussed/justified.

Authors: We made clear in the revised manuscript that the used Lagrangian techniques aim at giving a new view on velocity field in the North Sea. In other words, the paper is about velocity, not so much about turbulence. We do not analyse the propagation and mixing of particles. In our setup, particles released in NEMO are always advected in 3-D by (u,v,w). That is, the particles are neutrally buoyant (added in line 163-164) and can be interpreted as following the pathways of water parcels (Blanke and Raynaud, 1997). Because we study the properties of the velocity field, additional horizontal and vertical turbulent mixing is not introduced for particle tracking. As a consequence, the presented analyses are analyses of velocity properties and not of the effects of mixing (added in line 83-84 and 163-164).

Nevertheless, in terms of T/S, the water column is well mixed in January, thus the model physics can be treated as correct. The specific properties of the velocity field explains the difference of NCPD at the surface and bottom.

Implementations of turbulent mixing in Lagrangian tracking is mostly done by random walk schemes. The effect of horizontal diffusion is shown in Fig. R.2.1. We want to emphasise that the implementation of horizontal (van Sebille et al., 2018) and, in particular, vertical diffusion (van Sebille et al., 2020) in particle tracking are ongoing scientific subjects.

van Sebille, E., Aliani, S., Law, K. L., Maximenko, N., Alsina, J., Bagaev, A., et al. (2020). The physical oceanography of the transport of floating marine debris. Environmental Research Letters. https://doi.org/10.1088/1748-9326/ab6d7d

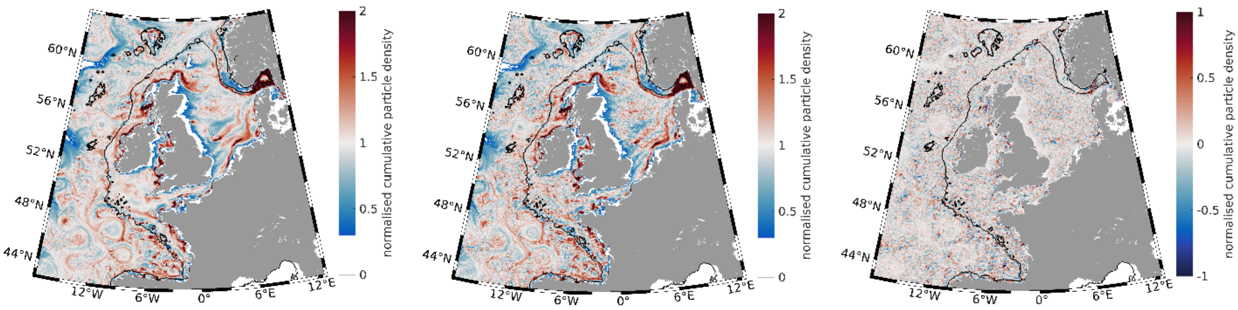

Fig. R2.1. Surface January 2015 NCPD without (left) and with (middle) additional horizontal diffusion in particle advection obtained from offline simulations. The right panel shows the difference without minus with diffusion.

Line 89: It is not clear whether the area of Fig 1 is identical to the AMM7 area, or if this is a subset?

Authors: It is a subset and has been added to the text (line 116-117).

Line 90: AMM7 is called a model, but perhaps “model setup” is more precise?

Authors: Done as suggested (line 95).

Line 93: Here the term “tracer” is used. It should be made clear whether tracer and particles are the same thing in this study.

Authors: Thanks for the hint. The use of “tracer” and “particle” should not be mixed up. Thus, Lagrangian particles have been defined (line 81-82) as well as the model tracers (T and S; line 102).

Line 95: Please provide a reference or justification for the choice of eddy diffusivity. It should be commented that this is constant throughout the area (which is not true in reality).

Authors: Please see, e.g. O’Dea et al. 2012 for a comparable setup of NEMO. The constant value of eddy diffusivity has been mentioned in line 104.

Line 96: Eddy viscosity should be a positive number.

Authors: Please keep in mind that we use biharmonic, not Laplacian mixing.

Section 2.2: More information should be given about the drifter type/characteristics/name, as near-surface drifters are affected by a varying degree of Stokes drift and wind drag, see e.g. Röhrs, J., K. H. Christensen, L. R. Hole, G. Broström, M. Drivdal, and S. Sundby (2012), Observation-based evaluation of surface wave effects on currents and trajectory forecasts, Ocean Dyn., 62, 1519–1533

Thus, a missing contribution from Stokes drift can possibly explain why the model currents are too slow in the comparison. Alternatively, SVP drifters (15m depth) from the Global Drifter Program could be used to validate the model current, so that Stokes drift would not be an issue. Also a plot of the complete drifter trajectories should be shown, to justify whether they cover a substantial part of the area, or just locally to their deployment location.

Authors: In this paper the focus is on analysing Lagrangian trajectories (no real drifters). As far as Stokes drift is concerned, please see our earlier publication (Röhrs et al. (2012) and Stanev et al. (2019) are now cited in line 324-325) as well as the one discussing technical details about real drifters by Callies et al. (2017) (line 132). The restriction to the German Bight is given in line 136.

Callies, U., Groll, N., Horstmann, J., Kapitza, H., Klein, H., Maßmann, S., & Schwichtenberg, F. (2017). Surface drifters in the German Bight: model validation considering windage and Stokes drift. *Ocean Science*, *13*(5), 799–827. https://doi.org/10.5194/os-13-799-2017

Line 148/Table1: The number of comparison points should be provided.

Authors: Added in the Table. Note the changed order of the Tables.

Section 2.3. This discussion is a bit messy, and does also belong in the results section, rather than under “material and methods”.

Authors: All results of Sect. 2.2 and 2.3 have been shifted to the results (note the rearranged order of the manuscript).

Line 184: It could be made clear (the first time) that Figure S2a refers to figure 2a in the supplements.

Authors: Done as suggested (line 252-253).

Line 207: could be commented that the Molinari and Kirway study is for the Caribbean during summer, thus quite different conditions.

Authors: This is correct and has been added (line 301).

Line 240: It should be commented (and discussed) that vertical mixing is not included.

Authors: The neglection of vertical mixing and how the movement of particles can be interpreted is added to the text.

Line 242: Should also be mentioned here that particles are released over the whole domain.

Authors: Done as suggested.

Line 244-246: The seeding locations of CR-V should also be shown on a figure

Authors: Showing the initial positions horizontally would require an own figure. Due to the amount of figures we decided to not add another one but to show these positions exemplarily for the lowest depth layer in Fig. 9e. We also improved the text accordingly (line 175-177).

Line 248: It should be mentioned explicitly that a separate offline trajectory model has to be used for the backwards simulations, as this is not possible to do with online simulations. However, a forward simulation with this offline model should also be done to benchmark it against the online forward simulations.

Authors: Such comparison has been made during the preparation of the manuscript and is mentioned in the text in line 151-153. The comparison in terms of NCPD using the results from an online run without vertical advection and the same setup in OpenDrift for January 2015 is shown in Fig. R2.2 (NCPD online minus offline). The differences are rather minor. In text, the necessity of an offline model has been added (line 151).

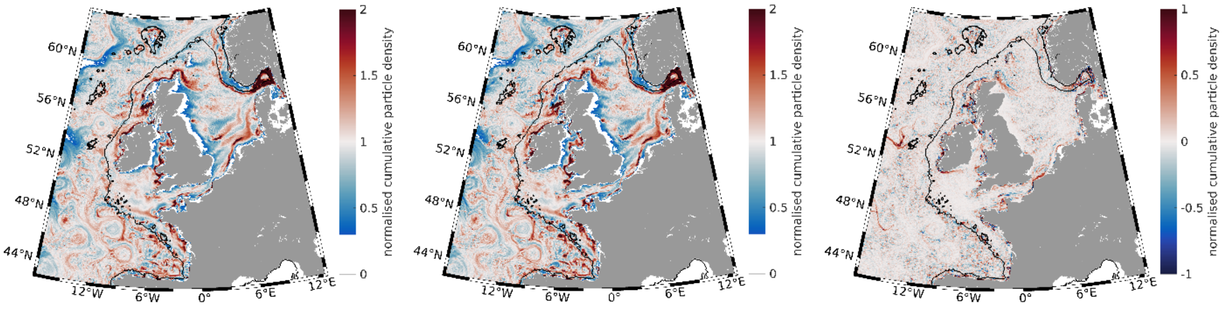

Fig. R2.2. Surface January 2015 NCPD online 2-D (left), offline (middle) and the difference online minus offline (right).

Lines 274-279: What would be the difference between "density trend" and "residence time"?

Authors: Residence time (RT) is defined as $\bar{t}_{\mathrm{w}} = \mathrm{V}_{\mathrm{S}}^{0}/\bar{J}_{\mathrm{V}}^{0}$ where $\mathrm{V}_{\mathrm{S}}^{0}$ is the total volume in the ocean reservoir and $\bar{J}_{\mathrm{V}}^{0}$ is the mean flux through the reservoir in unit time in case of a steady state (superscripted 0); see, e.g. Whitfield (1979). It measures the time needed to completely replace the volume of water in a certain oceanic region. If the RT is referred to an individual water element Y, the RT formula can be rewritten as $\bar{t}_{\mathrm{Y}} = \mathbf{Y}_{\mathrm{S}}^{0}/\bar{J}_{\mathrm{Y}}^{0}$, where $\mathbf{Y}_{\mathrm{S}}^{0}$ is the total mass of Y and $\bar{J}_{\mathrm{Y}}^{0}$ is its flux through the reservoir. In our study, Y can be interpreted as a particle. Then, NCPD would be the ratio of $\bar{J}_{\mathrm{Y}}^{0}$ and $\bar{J}_{\mathrm{Y,U=0}}^{0}$ with (u,v,w) = 0, because they are the sum of particles over a certain period of time. Although both fluxes have the unit [mass/time], the latter flux could be interpreted as $\mathbf{Y}_{\mathrm{S}}^{0}$, because it is constant in time. With this interpretation, NCPD is $1/\bar{t}_{\mathrm{Y}}$ with the unit [1/month]. That is, NCPD is proportional to the inverse RT (line 227-228).

Whitfield, M. (1979). The mean oceanic residence time (MORT) concept - a rationalisation. *Marine Chemistry*, *8*(2), 101–123. https://doi.org/10.1016/0304-4203(79)90010-0

Line 278: "motionless situation" is a bit unclear, please rewrite sentence.

Authors: Done as suggested (line 215-217).

Line 302-304: Please clarify what is meant here.

Authors: Done (line 352-353).

Line 461: extra space after "Channel"

Authors: Removed.

Section 3 is a bit lengthy, and hard to read due to jumping back and forth between the experiments and referring to many figures. Making it a bit more compact and structured would help.

Authors: We tried to split the sections into equally long sections as well as in a Eulerian and a Lagrangian results part. We also reordered the experiments according to their appearance in the text; same for the supplementary figures. The jumping between experiments and figures results from a manuscript structure which is based on certain physical topics. Therefore, it is inevitable to refer only to one experiment. The figure references are thought to help to orientate while jumping back and forth. We still find them helpful and decided to keep them.

Figures

There are a lot of composite figures/maps of the area of interest. These are quite small and hard to read when printed on A4 paper. Could whitespace be reduced somehow?

Authors: We reduced the white space as much as possible, especially in Fig. 2. Insets have been enlarged. All labels should be readable now.

In the figure captions, the letters a), b)... should rather be placed before the explanation, and not after

Authors: Done as suggested.

Figure 2: CR and NTE should be written explicitly as "control run" and "no tides experiment", so that the figure can be read and understood also before reading the main text. Same for other figures.

Authors: Good idea. Done as suggested. Same for NCPD.

Line 847: und -> and

Authors: Changed.

Figure 3: a bit much spaghetti here, perhaps use even fewer than every 5th trajectory?

Authors: We changed it to every 8th particle. For us, the present figure is a good compromise between visualising the currents for both the surface and bottom as well as covering most of the domain with trajectories. We also remark, that we will provide this figure in high quality to OS, so that the reader can zoom in and see specific details.

Figure 4: Caption is quite hard to read. The '+' and '-' symbols are presumably placed "by hand"? This is generally ok, but they are quite many, and sometimes slightly displaced, perhaps to avoid overlap? So in practice I don't think these symbols work very well here. Could the point be visualized by another, more objective measure?

Authors: For Fig. 4, NCPD can be interpreted as a quantitative measure for particle accumulation. Thus, we decided to avoid any of these markers and we emphasise, that we describe examples of pronounced features (line 373-375 and 565).

Figure 5: Title of lower figure is "monthly average", but I guess it should be "yearly average", or "average of months"

Authors: This is correct and has been changed accordingly.

References

Please update this reference, where you refer to a discussion paper: Dagestad, K.- F., Röhrs, J., Breivik, Ø., and Ådlandsvik, B.: OpenDrift v1.0: a generic framework for trajectory modelling, Geosci. Model Dev., 11, 1405–1420, https://doi.org/10.5194/gmd-11-1405-2018, 2018.

Authors: Done as suggested.