

We thank J. Kjellsson most sincerely for the time and large effort he expended on a thorough review of our manuscript. His valuable comments will definitely improve the quality of a revised paper.

In the following, the referee's comments are shown in blue.

1 Summary

The manuscript describes an experiment with surface drifters and model simulations in the German Bight. The goal is to assess the realism of the BSHmod and TRIM models. The authors compare six observed surface drifters (tracked for about 30-40 days) with simulated drifters using the two models. They find discrepancies between observations and models and discuss what could have caused them.

2 Overall comments

The manuscript is very well written with only a few misspellings and somewhat confusing sentences. While it is good that the authors give a detailed account of the drifter experiments, the main text makes a lot of references to maps in the supplementary material, which is split into multiple files and pages. I would recommend adding an extra plot or two in the main text where some results can be shown so that the reader does not have to go back and forth between the paper and supplementary material so often.

We agree that this is a problem. We tried to solve it by displaying now 12 example simulations (Figs. 7-9) rather than just eight (Figs. 7 and 8 in the original manuscript). To compensate for the additional figure, we removed the former Fig. 6, which just re-combined panels from different figures in the appendix. We believe that the additional figure much improves readability of Section 3.2, which has also been shortened by about 50 %.

I recommend this paper be accepted for publication after dealing with a few minor comments.

3 Specific comments

Parameters for including wind effects

How did the authors chose the parameters in Section 2.2.3? Did the authors try a few different values and tune the fields to match observations in this study, or was the tuning done in another study? If the parameters were tuned in another study, please cite that study and add a comment on how well it worked. If the parameters were tuned for the data in this study, the observations and models are not really independent and a validation can not be made. In the Discussion, the authors hint that no tuning was made. What was the motivation for choosing these values?

The following extra paragraph has been added at the end of Section 2.2.3, addressing this important issue:

"The assumed strengths of either wind forcing or Stokes drift resulted from trying to achieve an overall eastward displacement of simulated drifters that roughly agreed with observations. This approach must not be confused with sound model calibration, which seems impossible based on the very limited data available. Models perform differently during different periods and it is hard to distinguish, for instance, between deficiencies in the hydrodynamic model and implications of imperfect atmospheric forcing. Also independent data needed for model validation are not available. However, already the simple approach enables an appraisal of how successful drifter simulations will depend on a distinction between wind drag and Stokes drift."

At the end of the first paragraph of Section 3.2 this important aspect is emphasized once more: "A key effect of the inclusion of extra wind or wave effects is the intensification of westward transports in agreement with wind directions that occur most often. One should remember that achieving reasonable agreement between overall strengths of these transports in simulations and observations was the criterion which led to specific values we assigned to α or β in Eq. (1) (see Section 2.2.3)."

Page 1:

Line 21: "Lagrangian transport simulations also provide . . . "

Changed

Line 22: remove "for instance"

Changed

Page 2:

Line 3: ". . . as many of the input . . . "

Changed

Line 9: "However, the Eulerian surface currents . . . "

Changed

Line 10: "In cases of necessity, drifter simulations . . . "

Changed

Line 12: ". . . 5 m deep top layer. Therefore, even for an ideal . . . "

Changed

Line 13: ". . . of hydrodynamic currents."

Changed

Line 14: ". . . 1m deep layer".

Changed

Line 24-25: I found this sentence a bit confusing. "Although provided with . . . for instance.". Do the authors mean that the wave model is forced with the same atm forcing as the ocean model, and the Stokes fields are added "offline", i.e. after the ocean model and wave model fields have been integrated and stored? In that case, why not write something like "Stokes drift is calculated from the wave model using the same wind forcing as used in the ocean model."

The paragraph has been revised following also your suggestions: "*Waves and resulting Stokes drift were calculated using the wind forcing also employed for hydrodynamic simulations with TRIM.*"

Page 3:

Line 32-34: I found this sentence unclear. "After simulations . . . 25 h length." I understand drifters are split into 25 h segments, but what is meant by "different model setups explored the range of possible effects"? How were the setups different, and what were the effects?

Has been revised: "*First, full simulated trajectories are presented using currents from TRIM or BSHcmod, the latter also combined with wind drag and Stokes drift, respectively. A more detailed ...*"

Page 4:

Line 11: "of the drifter"

Changed

Page 6:

Line 8: "Eulerian model currents can usually not fully reproduce observed currents"

Sentence has been revised.

Line 17: How was α chosen? See comment above.

A new extra paragraph at the end of Section 2.2.3 now addresses this issue (see above).

Line 18: remove "a" and change "parts" to "part".

Changed

Line 21: ". . . when model currents used do . . . "

Changed

Line 22: How was 0.6% chosen? See comment above.

Again, the new extra paragraph at the end of Section 2.2.3 now addresses this issue (see above).

Line 23: "(1m deep top layer)"

Changed

Page 7

Line 10: I think Fig 4 is defined before Fig 3?

Yes, thank you for this hint! Sequence of the two figures has been changed.

Line 12: "A principal component analysis (PCA) was performed on the residual currents, focusing on the inner German . . . "

Changed

Page 8

Line 9: "a few days"

Corrected

Line 12-15: I found the two sentences really hard to read. "For each . . . existing observations." The time bar does not really show anything that has to do with the release of simulated drifters. I think the first sentence should be something like "The time bars show the durations of the surface drifters and different colours indicate subjectively identified drift regimes." The second sentence I think means that the time bars start at midnight, while simulations start at 13:00. Why not start the time bar at 13:00?

We agree. The modified Fig. 4 (now Fig. 3) now shows exact travel times of observed drifters. This made the rather complicated explanation you mention obsolete.

Line 29: ". . . of about 20 km from drifter 8".

Changed

Page 11

Line 7: "extreme drift speeds". It is hard to judge whether the drift speeds are extreme by just looking at maps. Could the authors include a time series plot of drift velocities instead, or a probability density function for speeds? Fig. 10 and 11 show this, so I would recommend moving that plot this section and perhaps include more drifters in it.

We followed this suggestion and moved former Fig. 11 to this section (now Fig. 6). The figure has also been expanded, now combining data for the four most important drifters 5, 6, 8 and 9.

Line 9: "moderate drift velocities". Again, hard to judge just by looking at maps.

A reference to Fig. 6 (former Fig. 11) is now included.

Line 20: How were these parameter values chosen? See comment above.

Described of parameter choice was improved. See our answers to the above comments.

Page 12:

Line 2: Somewhere here it might be good to remind the reader about how TRIM and BSHmod are different.

The following sentence was added: "*It appears that combining BSHcmod currents for a 5 m depth surface layer with either windage or Stokes drift brings corresponding simulations closer to both observations (Fig. 4) and simulations based on Eulerian surface currents from TRIM with 1 m vertical resolution (Fig. A4).*"

Page 16

Line 2-4: "Although . . . Eulerian currents." It is an important statement that adding wind effect gives the correct direction for drifter 7. It would be good with a plot or at least some numbers in the text where the the drift is shown for observations, TRIM, BSHmod and BSHmod+W (only TRIM and BSHmod+W shown in Fig 7).

The sentence was reworded to avoid misunderstanding ("*Comparing simulations based on BSHcmod+W (Fig. 8(a)) with those based on BSHcmod (SM2) reveals that the deviant simulation of drifter #7 arises from spatial variation of BSHcmod currents.*"). The deviating displacement simulated for drifter 7 is produced by differences in Eulerian currents. At the same time, adding wind forcing improves simulations of both drifter 7 and the neighboring drifters 5, 6 and 8 (as to be expected from the more large scale nature of wind fields). The additional figure for BSHcmod you are asking for is available from supplement SM2 (Please note: In SM2 we corrected all headers, now reading BSHcmod and TRIM, respectively. Former headers BSH_TOPLAYER and TRIM_3D_TOPLAYER were confusing. All data remained unmodified). In addition, supplement SM4 provides the results from using Stokes drift. Unfortunately, it seems hardly feasible to include these figures for one single situation into the main manuscript.

Page 17

Line 28: "An exception is drifter 9 . . ."

The whole sentence was removed to shorten the manuscript as requested by referee #1.

Page 18

Line 5: ". . . drifter 9 does not."

Sentence does no longer exist.

Line 16: "Although wind speeds can be relatively strong (not shown), strengths of 25 h. . ."

Again, the sentence was removed.

Line 20-22: "Note, however . . . locations.". I could not understand what is meant here.

Whole sentence removed.

Line 23: ". . . caused by the fast west-northwest movement of drifter 8, not shared by drifters 5 and 6 (SM3)."

Changed

Line 26: "A four-day period . . ."

The phrase has been deleted.

Line 32: "A particularly fast movement of drifter 8 is observed on days 34 and 35. On day 35, drifter 8 also drifts more westward than drifter 5 and 6."

First sentence was removed, second changed accordingly.

Page 19:

Line 13: "Southwesterly winds cause a transition towards a strengthened . . ."

Changed, but we kept the 'freshening', so it reads now "*Freshening southwesterly winds strengthen a cyclonic circulation.*"

Line 30: "Currents in TRIM representative of a surface layer of 1m depth had drift velocities similar to those observed (Fig 9)."

Changed

Page 20:

Fig 9: Why is BSHmod not shown in Fig a, or why are current speeds not shown in Fig b? It would be good to see what effect adding the wind effect actually has, i.e. what are the relative magnitudes of Eulerian currents and added wind effects? Also, the authors should consider showing probability distributions of errors in displacement and angles in order to condense the information. Does the error in angle have a zero mean or are the errors predominant in one direction? Does one model have smaller errors than the other?

We agree that the relative magnitudes of Eulerian currents and wind/wave effects are important information. Unfortunately, Fig. 9 (now Fig. 10) is already rather complex and one must be careful not to overload it. However, the manuscript provides the information you are asking for in Figs. 10 and 11 (now 12 and 6). From Fig. 10 (now 12) it can be seen that both windage and Stokes drift are much smaller than total Eulerian currents including tides. According to Fig. 11 (now 6), however, they become much more significant when considering residual currents (i.e. 25 h averages). The two figures also nicely show the mostly similar effects of windage and Stokes drift.

In response to the second part of your comment we introduced an additional figure (Fig. 11) that shows for both model approaches distributions of model errors:

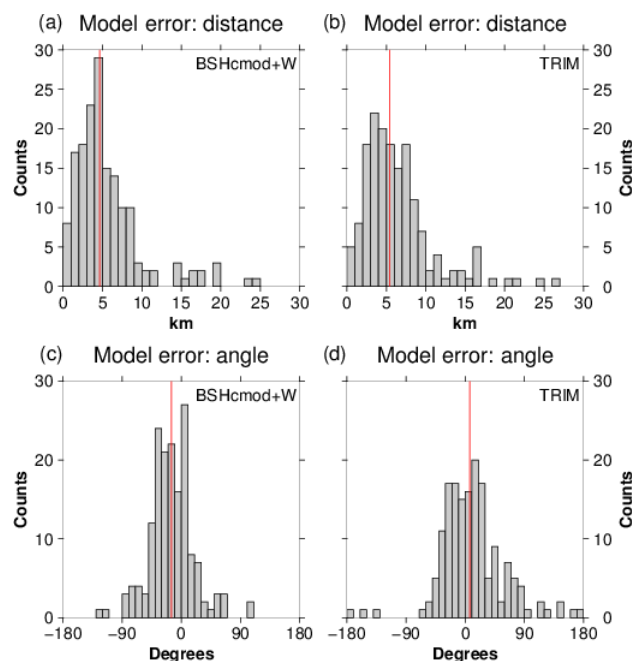


Figure 11. Distribution of model errors in 25 h drifter simulations. Histograms are based on 164 simulations in total for drifters #5, #6, #8 and #9. Referring to drift simulations based on BSHmod+W and TRIM, respectively, panels (a) and (b) evaluate spatial separations shown in Fig. 10(a). For the same set of 164 simulations, panels (c) and (d) evaluate directional errors from Fig. 10(d). Red lines indicate median values.

We doubt that the differences between the two models are statistically significant given the fact that the 164 simulations contributing to the distribution in Fig. 11 were made under very different environmental conditions. We discuss that in the revised manuscript.

Page 21

Line 9: what does "currents will generally not parallel winds" mean?

Replaced by: "*currents will generally not be in the direction of winds*"

Line 15: "... may be one of the reasons why simulated trajectories resemble each other ... "

Changed

Line 19-20: "Both TRIM and BSHcmod are unable to reproduce the specific ... "

Changed

Line 24: "... they start with small initial separations $O(1-10m)$."

The suggested change is part of a reformulation: "*Ohlmann et al. (2012) start with $O(5-10 m)$ initial separations to resolve initial non-local dispersion with exponential growth of the mean square pair separation, driven by eddies larger than the distance between the two drifters.*"

Line 29: "However, this separation might have been triggered ... "

Changed

Line 34: "could imply accelerated spatial separation". Why? How? I would rather say "and relative dispersion measured using drifters of different types may not reflect the diffusivity of the flow."

The sentence was revised accordingly.

Page 22

Line 4: "The subsequent separation rate of about 3 km per day ... "

Changed

Line 7: "... modelling was undertaken to ... "

Changed

Line 19: Somewhere here I think a discussion is warranted about the differences in wind forcing in TRIM and BSHcmod. What is the temporal and spatial resolution of the wind data? Do they capture variations on the same spatial and temporal scales?

Descriptions of BSHcmod and TRIM (Sections 2.2.1 and 2.2.2) have been extended accordingly. In both models atmospheric forcing is provided on an hourly basis. At this point, we added a sentence mentioning that more frequent HF radar observations might possibly enhance variability of drift simulations.

Line 20: Again, how were the parameters for your wind effects chosen. See comment above.

The parameter specification has already been addressed a couple of times (for instance, our response to your next comment below or our response to your comment at the very beginning of your list of comments). Therefore we do not see the need for getting back to this point in this paragraph that does not explicitly mention any wind parametrization.

Page 24

Line 1-4: Here the authors touch upon how the wind parameters were chosen, but it is not clear. Was the Stokes drift parameter chosen so that Stokes drift would be of similar magnitudes as windage effects?

The following sentences were inserted to explain this in some more detail: "*The criterion we applied for selecting α or β is that the overall eastward displacement of a drifter's location should roughly agree with that observed. A convincing confirmation of our selection was that the strength factors we chose worked consistently well for all drifters.*"

Page 25:

Line 1: "Fig 10 also shows magnitudes ... "

Changed

Line 4-5: "Variations of maximum drift speeds indicates that movements along different branches of ... "

Changed

Line 14: "Fig 10(a), magnitudes of drift velocities were smoothed using a 25 h moving average of hourly data"

The important point is that the original velocity vectors were smoothed rather than just their magnitudes. After restructuring the order of figures, the sentence now occurs together with Fig. 6: "*Fig. 6 provides magnitudes of velocities for drifters #5, #6, #8 and #9, calculated from velocity vectors smoothed using a 25 h moving average of hourly data.*"

Line 31-32: "Note that . . . wave effects." I think the authors mean they add Stokes and wind effects offline, i.e. after the Eulerian currents have been stored. Why not write "Note that the Stokes drift and windage was calculated offline and added to the Eulerian currents after the model had been integrated and the fields stored."

We followed this suggestion

Page 26

Line 2: What bulk formulas were used to include wind forcing in the TRIM and BSHcmod models? Same or different? Could the choice of bulk formula impact the results?

In Sections 2.2.1 and 2.2.2 it is now mentioned that the same parametrization of wind forcing is used in both models.

Line 9: "Two crucial and outstanding questions are a) are the drifters' behaviours representative of surface . . ."

Changed

Page 27

Line 1: "To fully disentangle . . ."

Changed

Line 11: "Possible reasons for the deviant behaviours of drifters 8 and 9 can only be speculated. "

Changed

Page 28:

Line 3: Could power spectra of kinetic energy show how important the sub-grid scale motions are?

We doubt that that would be successful. One must not forget that measurements were collected under very different wind conditions so that the data would have to be partitioned accordingly. Embarking on such detailed analysis and its uncertainties would open a new discussion beyond the scope of the present paper.

Line 8: ". . . wind speeds in this case. "

Changed

Line 19-23: This bit is hard to understand. I think it needs some rewriting. The sentence "Keeping in mind . . . Stokes drift" should probably be split into two sentences. Also "Accordingly . . . marine currents" should probably be split as well.

The paragraph has been reformulated, sentences have been shortened.