Final author response for the manuscript tc-2015-233 submitted on 24 Dec 2015 with the title:

“Sea ice diffusion in the Arctic ice pack: a comparison between observed buoy trajectories and the neXtSIM and TOPAZ-CICE sea ice models”

by Pierre Rampal, Sylvain Bouillon, Jon Bergh, and Einar Ólason

**Anonymous Referee #3**

Received and published: 17 March 2016

Dear referee,

First of all, we would like to thank you for your in-depth review, insightful comments and suggestions, which greatly helped us improving our manuscript. Like all the other reviewers you agreed on the interest of the sea ice diffusion analysis and suggested to emphasis that part of our work in the revised version, while reducing the weight given to the inter-comparison of the two sea ice models. We agree with this point and, therefore, largely restructured the manuscript following your recommendations and those of the other reviewers. Our manuscript is now entitled: “Arctic sea ice diffusion from observed and simulated Lagrangian trajectories”. In addition to the restructuring, we tried to answer your questions and comments as carefully as possible.

Below, you will find your original **comments in bold**, our answers in red and the **added text** to our manuscript in **bold red**.

**Please note that our new manuscript containing all the changes we made is attached as a supplementary material to the present document.**

**The study aims to evaluate the sea ice drift fields of two sea ice models with different ice rheology and coupling. They are mainly interested in sea ice diffusion accuracy of ice trajectory forecast as, e.g., needed for prediction of oil spill dispersion. In addition, the study derives useful metrics for ice diffusivity from buoy tracks.**

**In general, this is an interesting paper suitable for the Cryosphere. The model results and metrics derived from the buoys are, e.g., useful to guide future research on oil spill modeling in sea ice. The study provides, e.g., the time development of a potential oil spill search radius and which of the two model systems currently would be more suitable to predict the ice diffusivity more realistic.**

**The clear shortcoming of this article is that it is geared towards promoting the neXtSIM model system, which would not be a problem if the judgment always would be fair. This is not always the case. For example, the TOPAZ mean drift is too fast while the neXtSIM mean drift is too slow. While the too fast TOPAZ drift is mentioned and exposed several times the too slow neXtSIM drift is only mentioned at the margins. The study cannot solve the question if the difference in mean drift and diffusion observed between TOPAZ and neXtSIM is intrinsic to the models, i.e., ice rheologies, or the different initial conditions and atmospheric forcings (TOPAS: thinner ice, lower resolution forcing -> can cause faster ice and less drift fluctuations as observed here). While mentioned in the study these points should be stated more clearly. In the end, however, it is clear and I agree that neXtSIM performs better in the current setup than TOPAZ.**

We agree with the main remark of the reviewer, which is in line with the two other reviewers.

**We have adapted the manuscript to implement their suggestions.**

**Find more details comments below. After these points are improved I recommend the article for publication in the Cryosphere.**

**Page, line**

**1,1: I would suggest to add more information to the abstract about the buoy only results obtained in this study (e.g. p14, Fig.8), which are relevant for e.g. oil spill forecast. If possible this could also be reflected in the article title**

**We add this sentence to the abstract:”We discuss how these values are linked to the evolution of the fluctuating displacements variance and how this information could be used to define the size of the searching area around the position predicted by the mean drift.” and we change the title.**

**3, 59: the sentence sounds as if you are using the same buoy dataset as in Rampal, 2008, 2009. But this cannot be the case as the time series is longer. Do you mean you are using the same pre-processing? Otherwise why not reference the original IABP data?**

Yes the sentence was not clear.

**It is now clearly stated that it is the same method as in Rampal et al. (2009) that is used. The reference to Rampal et al. (2008) is not used anymore as it refers to another type of analysis of the same data.**

**6, 142: what is an “off-line float tracking system”? Mention that this will be described below.**

**This part of the text have been rearranged to be clearer.**

**6, 164: slab ocean: this is a strong difference to TOPAZ and the differences should be discussed more.**

Yes, you are right, that could have been important if we were interested by doing model inter-comparison.

**We dropped all the statement about model inter-comparison.**

**7, 176-179: if you are initializing with the TOPAZ ice thickness, why don’t you use that for the comparison of the two models? That would be much fairer. By increasing the ice thickness in neXtSIM but not in TOPAZ it can be expected that the ice in TOPAZ is moving faster for the same forcing. If possible you should repeat the experiment with the original not adapted TOPAZ ice thickness. You are not interested in the accuracy of the total sea ice volume here; you are interested in differences in the motion fields. The initial conditions therefore should be as equal as possible for the two model setups in my opinion. While I can understand that nothing can be done about that one is a couple ice-ocean model and the other is a ice model only, I cannot understand why you are introducing this artificial ice thickness difference here, which naturally will favor neXtSIM (because the ice thickness is pulled towards more realistic ice thicknesses every year).**

The two setups have not been designed to be compared. The setup (initial conditions, forcings and parameters) of neXtSIM is the same as the one used in Rampal et al (2015, under review) and has been defined to provide the best possible representation of the sea ice drift, thickness and concentration with the current version of the neXtSIM model running in a stand-alone configuration. The setup of TOPAZ is the same as the one used for the TOPAZ forecast and for the TOPAZ reanalysis. We did not use the TOPAZ reanalysis directly because the available outputs are not appropriate for a diffusion analysis: only daily fields and for the ensemble mean. Moreover the reanalysis for the period 1979-2011 was produced with a too high value for the air drag parameter leading to a much too fast sea ice. This has been corrected by the developers of the TOPAZ system but only for the reanalysis after 2011 and in the forecast system. We use the corrected value that was found optimal by the developers of TOPAZ (Internal technical report, available on request).

As our goal is not to compare the two platforms but just to give two distincts examples of the application of the diffusion analysis, we do not think it is useful to degrade the results of neXtSIM by using a setup more similar to the one used for TOPAZ. It would indeed be interesting to try to improve the results of TOPAZ but the task seems to us too ambitious and we limit ourself to us the default setup. We understand that the present exercise should not be presented as a strict comparison and we hope that the new version of the manuscript has cleared that ambiguity.

See also the answer to the main comments of the other reviewers.

**The text has been restructured and rewritten to avoid any “unfairness”.**

**7, 185-189: Also here, why are you using different atmospheric forcing for the two model setups? The ASR is a newer and mostly believed better reanalysis for the Arctic than ERAi. As ice drift strongly depends on the quality of the atmospheric forcing different results can be expected even if the same sea ice model would be used.**

neXtSIM uses ASR for this Arctic configuration because we found in Rampal et al. (2015, under review) that it allows us to have a lower RMSE than with ERAinterim when comparing the sea ice drift simulated by neXtSIM against observed sea ice drift from the GLOBICE dataset. Such sensitivity study to the forcing is not available for the TOPAZ system. The TOPAZ setup is defined on a larger domain also covering the North Atlantic, which is not covered by ASR.

**No changes**

**8,217: apart -> away (?)**

**Corrected**

**8,218: not a specialist on this but “steady and homogenous” sound like the wrong adjectives for a turbulent flow without mean flow to me.**

It is a common expression used in turbulence but we agree that it could be misleading. It means “steady and homogeneous in a statistical sense”, meaning that the characteristics of the fluctuating velocities (mean, variance,...) do not vary in space and in time.

**Corrected: by adding the term “statistically” before “steady and homogeneous” as it is also commonly used.**

**8,227: you have not mentioned what tau is exactly so far.**

We now add for clarity:

**“tau is the time interval for which the autocorrelation is defined”**

**9,263: what is k? The different buoys?**

k was the indice used to list “all the buoy velocities **u**\_k$ recorded at a distance less than L/2 from **x** and within the time window [t-T/2;t+T/2]”

**We modified that paragraph to avoid having to use this notation. We think it is much clearer now.**

**11,302-304: I actually cannot see that. I only see that for 2007. It is at least not as clear from the figures as you formulate it. Please adapt.**

Yes we agree.

**We shortened that paragraph and do not try to discuss the spaghetti plots anymore, but rather use these plots to justify the need of separating the mean and fluctuating motion.**

**11, 308: How is the artificial thicker ice in neXtSIM affecting this behavior? Would the difference be similar if neXtSIM would have used the TOPAZ ice thickness for initialization?**

The correction of the initial conditions positively impacts the results of the neXtSIM model. However we have not tried to quantify this impact separately from the other differences between TOPAZ and neXtSIM. As explained here above, the configurations of neXtSIM and TOPAZ used here are the default ones. Their design, tuning and validation have been done independently and presented in other papers and technical reports.

We have not run neXtSIM with uncorrected/biased initial conditions because it would require to redo the tuning and validation, which is out of the scope of this study, and maybe not very useful. We then cannot answer firmly the question. Note that the goal here is not to perform a sensitivity study of TOPAZ or neXtSIM but to illustrate the interest of the diffusion analysis.

**We add more details on the definition of the models setups.**

**12,337-345: Can you quantify these statements by numbers? I can see that TOPAZ is too fast. In e.g. 2007, however, it looks like neXtSIM is too slow and maybe also in 2008.**

The differences between the simulated and observed mean drift are quantified in the next paragraph by looking at statistical distributions.

**We changed the sentence “ The mean ice drift simulated by the neXtSIM model is much more similar to the observations in that respect.” Into “The mean ice drift simulated by the neXtSIM model reproduces well the mean circulation patterns, slightly underestimates the Beaufort Gyre but reproduces the almost immobile ice north of the Canadian Arctic Archipelago. ”**

**13,376: Maybe point out here that the majority of the IABP buoys are deployed on MYI.**

Yes, it is important.

**We add this sentence in the description of the IABP data:**

**“The buoys are mainly deployed over multi-year ice and then do not represent the dynamics of weaker seasonal ice.” and add “multi-year" to “...may indicate that multi-year sea ice dynamics are dominated...”.**

**13,395: This paragraph gives a good summary of possible causes for the observed differences, which I agree with and which should be summarized in the conclusions again. Your goal, however, is to separate the differences caused by the two ice rheologies. How can you achieve that goal if the forcings, thickness etc. are so different that they affect the results?**

The goal is not to compare two rheologies but to illustrate the interest of the diffusion analysis.

**We modified the text in many places and the structure of the paper to emphasis on the diffusion analysis, and to better explain the differences between the two model setups.**

**15,445: The last two paragraphs actually give interesting and useful information derived from the buoy dataset only. This information is independent from the model comparison. Maybe it would be easier to find for the reader if summarized in an extra sub-section. Also from the abstract I would not have expected to find such information here. Mentioning it could widen the readership.**

Yes, you are perfectly right.

**We changed the structure so that these two paragraphs are now in the first section on the diffusion analysis. These results are also now mentioned in the abstract and conclusions.**

**16,472: Before you were always giving T in days**

**Corrected**

**16,471-502: you should clarify that you are talking about the buoy results not models here.**

yes.

**The analysis of the buoys is now discussed separately in the conclusion.**

**17,508: The TOPAZ circulation pattern looks right just the magnitude is a bit off.**

We do not agree. The mean drift along the CAA is clearly problematic and could not be corrected by simply applying a multiplicative factor.

**We changed the sentence to be more specific: “The mean velocities in the simulations using TOPAZ… do not represent correctly the circulation near the Canadian Arctic Archipelago.”**

**17,509: Yes, but mention again that neXtSIM is too slow and that these differences for the mean fields well can be due to the different forcing and ice thickness and not the models themselves.**

**Corrected. We know mention the low bias and we change the formulation into:**

**“The mean velocities in the simulations using TOPAZ...” and “The mean velocities in the simulations using neXtSIM” to avoid unsupported generalisation.**

**17,520: Doesn’t look to me that TOPAZ was tuned the same way regarding the ice thickness as neXtSIM and using better atm. forcing also does not sound like finer tuning to me.**

The two setups used here are the default ones defined for other studies. Both of them have been tuned differently and independently.

**We know better describe those differences in the text and in the conclusion.**

**18,524: add a few more introductory sentences. After reading the paper it was not clear to me where the Appendix relates to the rest of the paper.**

**The content of the appendix has been transferred to the introduction.**

**19, 572: Research Council?**

**Corrected**

**25, Fig.4: I see three lines: thin black, thick black, red. You only describe two in the caption.**

**Corrected**

**26, Fig.5: mention what L is in caption or shorten whole caption.**

**Corrected**

**29, Fig. 8: Hard to see anything in the upper plot**

**Corrected**

**31, Fig10: color scale and annotations impossible to read.**

**Corrected**