Response to Reviewers for Paper: "Dynamical reconstruction of the upper-ocean state in the Central Arctic during the winter period of the MOSAiC Expedition."

Reviewer 1: *The article presents a model reconstruction of the Arctic Ocean structure during the winter period of the MOSAiC Expedition. The authors used the FESOM2 model with an altered turbulence closure scheme at high resolution. The model results were nudged using profile measurements from buoys, and evaluated against an independent set of profile measurements. The resulting model simulation shows signs of enhanced eddy kinetic energy around the halocline and the depth of the warm Atlantic Water.*

While the method seems by-and-large reasonable, in my opinion additional work needs to be done in the analysis and the description of the work in order for it to be ready for publication. A few general comments:

The authors should clarify the language used throughout. While the methods describing nudging the model using the data, the phrase "nudging of the data" is frequently used, implying that the data where being altered by the model. This should be clarified.

Response: The authors are grateful for the reviewer's overall feedback and find it highly valuable. The specific points raised have been addressed in the following sections. A small remark: we are developing and using the FESOM-C model, not the FESOM2 model. Although these models are from the same family, their differences are described in the article.

The phrases have been changed to "model nudging" or "model nudging to data" throughout the text.

Reviewer 1: *In its current form, the introduction reads like a list of relevant papers. The paper would be strengthened by integrating the results of prior work into a description of the state of the science for the relevant processes, instead.*

Response: We have revised the introduction to provide a better flow, leading up to the objectives of the manuscript. Selected citations have been added or removed.

Reviewer 1: *The authors find that there are discontinuities introduced by locations where the trajectories of the buoys form loops. In my mind, this indicates that the ocean is evolving and that treating the observations as a frozen-in-time snapshot is a problem. Perhaps it makes sense at certain time scales and for certain depths.*

Response: We concur with the reviewer that duplicate data introduces uncertainties in data interpretation. For instance, it is unrealistic to expect congruence in measurements taken at different phases in the context of inertial waves. This is one of the reasons we implemented a 1 km distance in our nudging method (refer to line 228) within the "loops" region where the model approximates the data. With this approach, especially in areas where trajectories intersect and the data resolution is high, the values for nudging are smoothed, preventing the formation or disruption of a baroclinic front. This also enhances the stability of the model's solution.

In scenarios where ocean dynamics undergo significant changes (relative to

ice drift) within a region containing rapidly moving eddies, we address this in our example concerning eddies movement in a model without nudging. In such cases, data interpretation necessitates modeling without nudging, thereby rejecting the quasi-stationary approximation assumption. However, as illustrated in Figure 5, a free run does not substantially alter the mean characteristics of the reconstructed fields. Generally, intersections of buoy trajectories are brief, spanning short durations relative to the several months over which measurements are conducted.

Reviewer 1: *The colormaps used in Figure 9 and 7 should be replaced with colorblind-friendly and print-safe colors.*

Response: The colormaps of Figures 9 and 7 are changed in the revised manuscript.

Reviewer 1: *Minor grammar and typography errors throughout, some are listed below.*

Response: All minor comments are addressed in the revised manuscript.

Reviewer 1: *More importantly, it's not clear to me what the key contribution of the paper is. This is not to say the work isn't valuable or worthy of publication. Rather, I think that substantial revision of the introduction, discussion, and summary is needed to clarify the importance of the work. Clearly a lot of thought and effort have gone into this, and I think restructuring the presentation can bring the value of the work more clearly into focus.*

Response: The introduction is rewritten in the revised manuscript. Additionally, the discussion and summary sections are modified to emphasize the main messages of the article regarding the potential application of nudging for reconstructing three-dimensional fields in this experiment, with implications for their use in other research. This also includes a demonstration of the distribution of Eddy Kinetic Energy (EKE) in the central Arctic region.

Reviewer 1: *A few (non-exhaustive) minor comments:*

6 "drift speed direction" = "drift speed and direction"?

corrected

13 "And no" – "Simulations show no..." or something like that?

corrected

18 capitalization unnecessary for "earth system models"

corrected

21 Grammar unclear

corrected

31 Grammar

corrected

75 "so-called" implies that there is some doubt in the name. The site is called Ocean City

corrected

80 Define "DN"

corrected

85 "one possible method are" grammer incorrect, could replace with e.g. "one possible approach is to use interpolation techniques"

corrected

191 DN buoys trajectories → "DN buoy trajectories" or "trajectories of the DN buoys"

corrected

193-4 "these interlacement" unusual word choice, I'd rephrase for clarity

corrected

195-196 – Why would we expect the measurements to be the same after a repeat visit? I don't understand why this would lead to aliasing of a signal.

Aliasing of the signal occurs only in a quasi-stationary approximation during spatial analysis, such as in the case of horizontal interpolation. The phrase has been removed to prevent confusion.

203 (and throughout, including in the summary). "Nudging of the data" implies that you are altering the data. Is it not the case that you are nudging the model using the data?

Certainly, the model is nudged to the data. Changed throughout the text. Confusion due to "data assimilation".

400 – What is meant by "or October 2019 to January 2020" here?

From October to January, the DN drifted within these geographical boundaries. The sentence has been reformulated.