Authors' Response to Reviewer Comments

The authors would like to thank the reviewers for their insightful feedback and constructive comments. We have addressed the concerns and/or incorporated each suggestion to strengthen our manuscript. Please note that each of the reviewer's comments, denoted in *italics*, is addressed below.

General comments:

This paper documents the assembly of a database of lagrangian drift tracks that includes many of the variables needed to study changes in the surface energy budget (SEB).

They assert that the database can be used to study a range of SEB processes, and present some results from the assembled dataset. However, the authors also show that the drift tracks have mean errors of 82.6 km, and can be as high as 500 km in certain areas, so the "tracks" are probably not actually following the same parcel of sea ice.

Authors' Response:

Thanks for your comments. The accuracy of the Lagrangian tracks certainly plays a role in the accuracy and usefulness of this database. We've added some discussion points addressing this (see below) and still believe this database to be useful for large scale analyses. While the day to day changes in parameter values may not be realistic, the long term or cumulative effects of these parameters on a sea ice parcel can be used for subseasonal to seasonal analyses.

Detailed Major Suggestions and Comments:

1. *The paper needs a good scientific hypothesis or question to guide the research.*

   This paper jumps into the middle of the scientific process by first producing a database, then trying to find questions that the database may help answer. A more fruitful approach would be to find a scientific hypothesis, then assemble data to test that hypothesis.

Authors' Response:

There are several hypotheses tied to this project at large which drove the formation of this dataset, but this is the preliminary manuscript meant to introduce the database and potential uses. With the recent push for open science in the community, we felt it necessary to publish methods and rationale used to create this database rather than focus on specific scientific insights as has been done in the past (Liston et al., 2020; Pfirman et al., 2019; Tschudi et al., 2010).

2. *Mean errors of 82.6 km for the lagrangian tracks may or may not be large depending on the scientific question a person is trying to answer.*
   a. *For example, if one were trying to understand the roll of large scale cyclones, then this probably is not an issue, but if one were trying to understand the small scale changes in ice concentration, then this error is unacceptable. Looking at Figure 1, the authors mark a 25km x 25 km box. A shift of even just a few km, shows that we are looking at an area of much higher sea ice concentration than the sea ice parcel that is highlighted. The SEB in the marked pixel is much different that the SEB in the parcels surrounding this.*
   b. *If the mean errors are this large in reproducing the tracks of a buoy that is included in the gridded ice motion database, how much larger are the errors in areas without buoys?*
   c. *Given the errors in reproducing lagrangian tracks, why not just use the actual drift tracks of the buoys? For example, the Ice Mass Balance buoys measure many of the quantities assembled here.*

d. *Section 3.2.2, and Figure 5: Are the differences seen in each of the panels due to real physical changes in the parcel compared to the buoy observations, or due to errors in the lagrangian tracks?*

Authors' Response:

a) Thanks, yes this database is better suited to large scale analyses rather than fine temporal/spatial analyses. Many of the hypotheses we wish to address in future work are concerned with longer term (weekly/seasonal) influences of atmospheric parameters on sea ice. In this regard, the database captures summary statistics well. Table 1 below shows the average difference of maximum, mean, and minimum values of parameters between individual buoys and the associated Lagrangian sea ice parcel. We've added some discussion of this in Section 3.2.1.

Table 1. Average differences of the maximum, mean, and minimum value of parameters between IMB buoys and Lagrangian parcels.

Variable	**Maximum**	**Mean**	**Minimum**
AirPressureDiff	1.17	-0.07	-1.60
AirTempDiff	0.74	-0.88	-2.80
IceThicknessDiff	-0.33	-0.01	0.45
SnowDepthDiff	-0.06	-0.02	0.01

b) Conducting a detailed validation of trajectory accuracy is difficult because most observations of sea ice drift (for example, buoys) are included in the sea ice motion product. However, Tschudi et al. (2010) compared the drift of the Surface Heat Budget of the Arctic Ocean (SHEBA) ice camp with sea ice parcel tracks using this same Lagrangian method and found an error of 27 km over 293 days.

c) The benefit of creating this database using Lagrangian tracks rather than buoy drift tracks is that we can create a much larger database. Our database contains over 1 million tracks. However, creating a database using buoys as you've suggested could be a nice supplement to the database we've created and could be done in the future.

d) The simple answer is both, but we've now done an analysis of parameter errors caused by errors in location. We've compared parameter errors due to misplaced trajectories and errors due to modeling/sampling errors by interpolating common parameters from the input datasets to the true locations of the IMB buoys with the same methodology that was used for our Lagrangian tracks. For this comparison we now have parameters produced in our Lagrangian tracks database (Ldata), parameters produced with the same methodology but with the true buoy locations (Bdata), and the observed data from the buoys themselves (Bobs).

By comparing the differences between Ldata and Bdata (because they have the same input data the differences are due only to location differences) with Ldata and Bobs we get a sense of errors due to location differences. Figure 1 shows this comparison with points colored by distance between the Lagrangian track and the buoy. The results highlight three main points:

1. For air pressure, when ice parcels are large distances away from the buoy the main source of error is the distance between Lagraingian tracks and true locations as indicated by the points on the 1-to-1 line, specifically points that are a large distance away. Otherwise, when the points are not separated by large distances the main source of error is due to modeling/sampling.
2. For sea ice thickness and snow depth, inaccuracy of parcel location does contribute to parameter errors, but this is true even at small distances as indicated by the roughly linear relationship regardless of distance. This suggests that the spatial variability of these variables is so high that unless the location is exactly correct (unrealistic) some error will be present.
3. Most of the error in air temperature is due to modeling/sampling errors as indicated by the wide horizontal spread, little vertical spread, and well mixed distances.

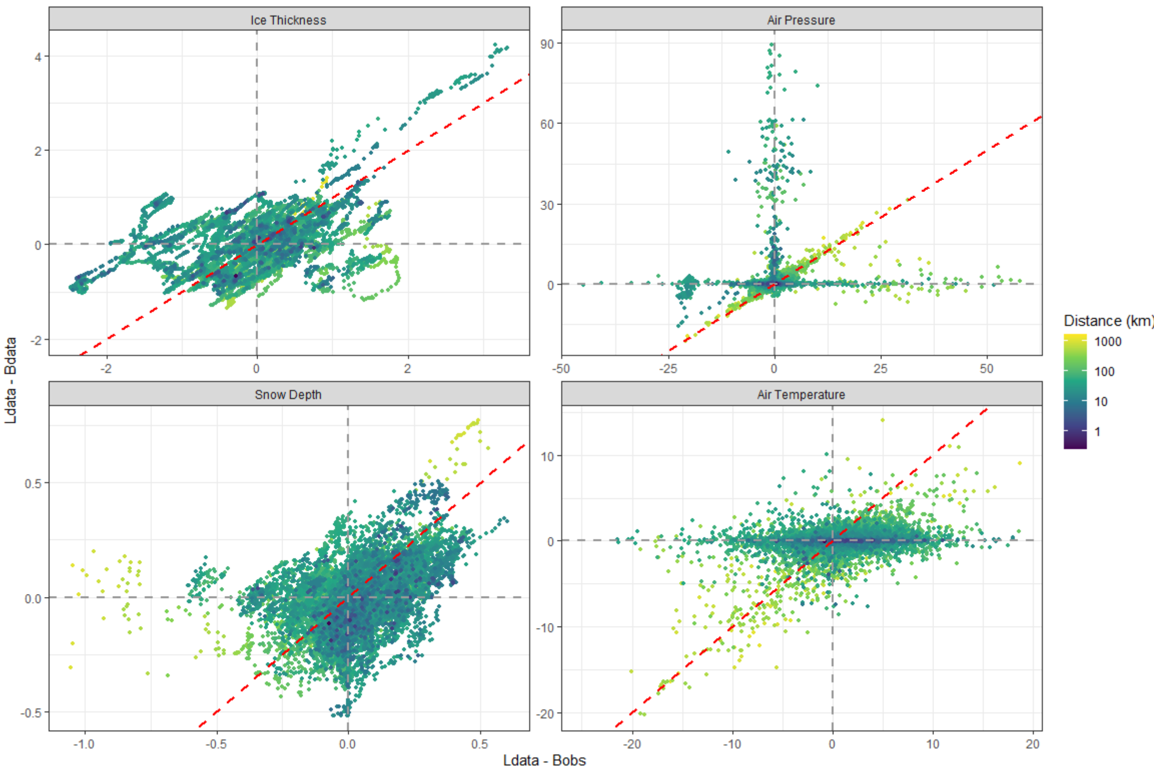

Figure 1. Influence of location errors on parameter errors. Color bar shows the distance between the Lagrangian track and the buoy (on logarithmic scale for clarity). Gray dotted lines mark zero for each axis, red dotted line shows the 1-to-1 line.

3. *All the different datasets assembled here also have their own errors. As with comment 2 above, whether these errors are acceptable depends on the scientific questions we are trying to answer.*
   a. *One thing to note is that a "lagrangian approach" may also be taken by directly using many of the disparate datasets they assembled here. For example, PIOMAS includes many of these variables as forcing or as estimates from the model. PIOMAS is well documented so the errors,*

biases and uncertainties are known. The model can give us a "self consistent" framework to do lagrangian studies by tracking a parcel using the ice motion provided by the model.

b. *By assembling disparate datasets as is done here, we lose the "self consistency" of each data set and quantifying the errors in our results becomes difficult. Following example, looking at figure 9, the sea ice thickness obtained from PIOMAS starts declining in May long before the onset of melt derived from AIRS skin temperatures. How can we explain this given the variables assembled?*

c. *Sea ice thickness also increases in PIOMAS just before the onset of melt in June (Fig. 9). What forces this change? Or is there simply a shift in the pixels that they are tracking?*

d. *A more thorough discussion of errors for each dataset should be included in section 2*

Authors' Response:

Thanks for pointing this out, this is a good point. Due to the uncertainties in all the input datasets, small scale analyses using our database may not be appropriate. The daily changes you point out in Figure 9 are a good example of this. However, the cumulative effects of atmosphere-sea ice interactions from the database can be used for studying the fate of sea ice (i.e. whether a parcel survives the summer melt season) as mentioned earlier (response to comment 2a, Table 1).

You make a good point that we are incorporating errors from each data source into this database, but using multiple data sources for the study of sea ice is often done. We've included many atmospheric and sea ice/snow variables in the hope of a wide range of uses of this database, but all variables do not necessarily need to be used in conjunction.

4. *Reading through their abstract and conclusions, the primary contributions of this paper to science are: 1) they produced a lagrangian data base, and 2), they find an increase in the number of sea ice parcels over time. Both these findings are moot given that they may not be tracking the same parcel of sea ice, and since they note that their lagrangian drift tracks are significantly slower near Fram Strait where most parcels of sea ice is exported from the Arctic. The increase in sea ice parcels over time can probably be attributed to more of their parcels "surviving" since less are exported through Fram Strait compared to the real world.*

Authors' Response:

Thanks for your comment. A third major contribution is including terms for calculating the surface energy budget, the usefulness of which is demonstrated in Section 3.3.1. The increase in the number of sea ice parcels over time is likely due to increased variability in sea ice conditions, in particular sea ice concentration. As the generation/termination of sea ice parcels is determined by the 15% concentration threshold, counting the number of parcels that are generated/terminated is essentially a quantification of the variability of low sea ice concentrations.

As mentioned above, the aim of this manuscript is to introduce this database and to show some examples of its use. With the recent push for open source scientific research within the community, publications of this nature are not unheard of (Liston et al., 2020; Pfirman et al., 2019; Tschudi et al., 2010). There are several hypotheses tied to the funding of this project which drove the creation of this database and will be addressed in future work.

Minor suggestions and comments:

Line 35: Change "known as" to "attributed to".

Thanks, changed.

Figure 5: Add units to each row of plots.

Thanks, changed.

Figure 7a: separate FYI and MYI bars so that we may be able to see any differences or trends from year to year. Interspersing FYI and MYI as shown makes it hard to see things.

Thanks, changed.

Figure 9: Mark cyclones as in Fig. 10. It would be interesting to see if cyclones are related to the changes in in snow depth, or sea ice thickness shown here.

Thanks, changed.

References:

Liston, G. E., Itkin, P., Stroeve, J., Tschudi, M., Stewart, J. S., Pedersen, S. H., Reinking, A. K., & Elder, K. (2020). A Lagrangian Snow-Evolution System for Sea-Ice Applications (SnowModel-LG): Part I—Model Description. *Journal of Geophysical Research. Oceans*, *125*(10). https://doi.org/10.1029/2019JC015913

Pfirman, S., Campbell, G. G., Tremblay, B., Newton, R., & Meier, W. (2019). *Lagrangian Ice Tracking System: LITS Expanded with Arctic and Antarctic Environmental Data*. *2019*, C22D-03.

Tschudi, M., Fowler, C., Maslanik, J., & Stroeve, J. (2010). Tracking the Movement and Changing Surface Characteristics of Arctic Sea Ice. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *3*(4), 536–540. https://doi.org/10.1109/JSTARS.2010.2048305