General response:

We would like to thank the two anonymous referees as well as Peter Morse for their constructive and thorough evaluations of our manuscript. We appreciate the time taken to provide feedback, which has helped to improve the clarity of the paper and the usefulness of the ABCFlux v2 database. We have addressed all the referees' comments in the revised manuscript, as detailed in our point-by-point responses below.

To address Peter Morse's comments, we have revised the thaw categories following the proposed suggestions. The thaw categories are now: Active layer thickening with subsidence, Active layer thickening without subsidence, Active layer thickening with talik formation, Ice-wedge degradation, Thaw lake/pond expansion, Wetland collapse, Active layer detachment sliding, and Retrogressive thaw slumping.

In addition to the changes to the thaw categories,we have made minor updates to the dataset, which necessitated adjustments to some figures and values throughout the manuscript (e.g., the number of sites listed in Table 5). The specific modifications to the dataset are outlined below:

- Cherskii Tower Data: We have included data from the Cherskii tower. While this site is technically an experimental setup, it is designed to mimic nature-induced warming and provides a high-value, long-term time series. It has been flagged with expert flag 4 to denote its significant land use change from humans.
- YK1 Tower Data: Following correspondence with the site Principal Investigator, we have removed the data spanning September 2019 to September 2020.
- Mukhrino Tower: We identified and removed duplicate entries for the year 2015.
- Thaw Categories: All records have been reclassified according to the updated categories detailed in our response to Peter Morse.

To ensure the Tracked Changes version remains legible and focused on the reviewers' specific feedback and content revisions, we have implemented minor updates to those numbers and figures directly without highlighting them in the Tracked Changes document.

RC1 General Comment: Following on the release of ABCFlux v1, this v2 dataset is generally an improvement to v1 in every way. An increased amount of data has been included in this new release, covering more years of data, aquatic sites with substantial corresponding flux data, as well as CH4 data. The scope of the dataset is impressive, as is the work that has gone into curating, filtering, and aggregation of the data. Additionally, substantial effort has been spent to document and summarize the dataset, the processing behind it, and all the associated ancillary data and metadata - a commendable accomplishment. This is indeed necessary for such a large, disparate dataset that includes such a substantial number of sources and workflows, and is critical to prepare the data to be used as a single product for Arctic and Boreal ecosystem analysis, the intention the

authors have. Particularly improved from v1 is the move to standardize the temporal interval to a consistent time step for analysis, though by their own admission, not all sites have consistent time series data due to screening or lack of data, something that would be invaluable to assess fluxes over growing seasons. Still, having data at standardized time intervals allows this dataset to be further used by researchers interested in analyzing coincident data sources. Additionally, the improvement of land status and vegetation detail in this dataset will further benefit terrestrial researchers interested in community composition connected to fluxes.

While this dataset is incredibly valuable given its scale and breadth, one still wishes for a similar dataset with higher flux resolution with a similar level of screening and unified processing. Additionally, while the value of this dataset is its compilation consistency allowing for cohesive analysis, resources do exist that offer options for viewing and assessing the amount of flux data available globally as well as within specific domains in raw forms.

Response: We thank the reviewer for their positive assessment of ABCFlux v2 and for recognizing the substantial effort involved in curating, filtering, and standardizing this dataset. We are pleased that the reviewer found the inclusion of detailed vegetation and land-status metadata to be valuable improvements.

RC1: The ARGO data tool mentioned on line 1171 is a great resource for viewing and accessing Arctic and Boreal flux datasets. The value of the ABCFlux v2 dataset is the processing, screening, and cleaning that has gone into homogenizing all these diverse data sources. The ARGO data tool references ABCFlux v1. It would be great if the current version of this dataset could synergize more directly with that.

Response: ARGO has been updated to include all sites included in ABCFlux v2, and we also cross-checked ARGO when preparing v2. For some sites included in ARGO, however, we did not find openly available data, or the data were available only in a seasonal format. Furthermore, new sites have been added to ARGO since our data compilation, which explains some of the mismatches. We have revised our description of ARGO to clarify the links between this database and our dataset (see lines 1212-1215).

RC1: It is clear from the detail in this paper that a significant amount of time has been spent listing and assessing all the harmonization efforts and where discrepancies exist. I found that I was sometimes reading similar details throughout the document, and at times would lose track of which section I was intended to be in. With the massive amount of detail that needs to be conveyed, I am not sure the best way to streamline this aside from making the authors aware of it. An example would be “For sites without monthly aggregated fluxes available, we present the fluxes as seasonal values and provide the start and end date of the measurement period.” (Line 497) This was approximately said on line 458 and feels redundant here. Could it be combined or streamlined?

Response: We removed the redundant statements and did our best to streamline while retaining the critical information.

Example: We changed line 458 to read “However, there were some seasonally-aggregated data from previous syntheses and studies that we were not able to incorporate in a monthly format; these were kept in the dataset in seasonal format alongside the start and end date of the measurement period.” and line 497 was removed

RC1: The location of these flux measurements (specifically tower data) is described in table 3 on line 643 as being as detailed as possible. Historically, one issue with flux tower location estimations has been the precision of the tower location, sometimes being off by 10s to 100s of meters (I should say in the cursory analysis of a few plots in this dataset, all plots seemed to generally line up well with the towers). Still, for some of these community datasets, potential offsets make alignment for cross-analysis with other data sources difficult, including scaled community composition and site specific data from other sources, which in harsh environments like the Arctic can turn over quickly. One benefit to this dataset would be a more precise alignment of these points with overall harmonization, though that shouldn't be a constraint on publication, just a suggestion.

Response: We tried to provide precise coordinates when possible but not feasible for all sites. We were often limited by the precision provided in publications. We added a sentence describing this uncertainty to variable descriptions listed in table 3.

RC1: I really like the map style (Figure 1, line 475), but the sheer amount of data contained in them in v2 makes it hard to get a clear picture of where data is and how much exists. The zoomed-in versions in the supplement are much clearer, but they only cover a few areas. Areas within Canada, particularly around the BERMS site, are hard to decipher. It would be great to have higher resolution maps for all major plot regions. Also, the map appears to be tilted where v1 seemed more north NADIR. The v1 version was a bit more legible. Additionally, on line 1350 you said “Moreover, the studied sites are heavily clustered in a few regions in Alaska and Fennoscandia, therefore leaving significant spatial gaps in coverage in spite of the relatively high absolute number of locations. In particular, despite Russia’s large land mass (close to 60% of the domain), data from Russia only comprise 10.8% of the dataset in terms of site-months and 15.3% of sites in ABCFlux v2 (with similar representativeness among terrestrial and aquatic data), making this region a critical data gap.” This makes sense, but I wouldn't let this be the reason to not render maps for all plots.

Response: We made maps for Russia/Mongolia and Canada and added them to supplement figure 8.

RC1: The data is listed as Terrestrial and Aquatic in Figure 2 (line 479). The data repositories are listed twice, and NEON is listed on the bottom box but not the top (I realize AmeriFlux would contain NEON data). Some figures have terrestrial or aquatic in parentheses, but others don't, and it's hard to know then what is what. I would suggest

improving the terrestrial/aquatic separation. Also, is the community contributed data intended to be in the middle covering both?

Response: We added colors to the flowchart to help distinguish between terrestrial and aquatic. NEON is not listed under the terrestrial data repositories as we only listed repositories we access directly and as you stated NEON data is available in Ameriflux. NEON is listed under the aquatic repositories as gas concentration data was downloaded directly from NEON. We clarified this in the figure caption.

RC1: I found expert_flags very valuable and informative (line 900).

Response: We are glad you found them useful

RC2 General Comments: Virkkala et al. present the ABCFlux v2 database and a manuscript describing the content and usage of this database in great detail. ABCFlux v2 presents the most comprehensive collection of CO2 and CH4 flux datasets of the boreal and Arctic region in a single, homogenized database. In addition, the database contains observations from hemiboreal sites, which may be representative of the present-day Arctic–boreal region under future climate change. The database includes observations from different types of terrestrial ecosystems, wetlands, and inland waters, and is based on different methodologies, including flux towers, chamber measurements, bubble traps, and estimates of CO2 and CH4 diffusive emissions from inland waters based on measured concentrations and estimated gas exchange velocities. Data were taken from different existing databases, repositories, and scientific papers (including unpublished data contributed by the authors). The database and accompanying MS feature a long list of co-authors, including the different data contributors who actively helped to homogenize the data, contribute meta-information on study sites and methods, and flag potential pitfalls or sources of uncertainty.

Overall, the MS is very well written and describes the database, the contained data, and its sources in great detail. Here I have only minor comments.

The database can be downloaded from the ORNL DAAC repository. It comes in a flat file format (.csv), which saves storage space and can easily be imported into most types of database management systems, statistical programs (incl. MatLab, R, Python), or simple spreadsheet software (incl. MS Excel and LibreOffice Calc). The database is represented by a single large table with 141 columns, due to the large amount of meta-information provided. This high number of columns provides a plethora of meta-information, but makes the table rather hard to follow. Given that many of these columns apply only to either terrestrial or freshwater ecosystems, I would suggest splitting the table into two: one for terrestrial ecosystems (incl. wetlands) and one for freshwater ecosystems (lentic + lotic). That would save additional storage space and make the two tables easier to navigate, while not contradicting your idea of containing both terrestrial and freshwater ecosystems in one database.

I think this database is a great contribution to the Earth system science community. However, I would still suggest splitting the table to make it easier to use. As this should be easily feasible, and as the MS is very well written and very complete, I suggest publication after minor revisions.

Response: We thank the reviewer for their assessment of the ABCFlux v2 dataset and for the constructive suggestion to improve its usability. We agree that a single table with 141 columns can be difficult to navigate, particularly given that many metadata fields are specific to either terrestrial or aquatic ecosystems. Consequently, we split the dataset into two separate files: one for terrestrial ecosystems (including wetlands and uplands) and one for freshwater ecosystems (lentic and lotic). This restructuring significantly enhances the ease of use for researchers focusing on a single domain while maintaining the homogenized formatting and column naming conventions.

RC2: L403-404 : The beginning (“Non-eddy covariance measurements of”) doesn’t fit here

Response: We deleted 'Non-eddy covariance measurements of' from this sentence.

RC2: Table 1: Maybe you could highlight that for freshwater systems, you do not have any observations for plant mediated CH4 emissions. You had mentioned that flux earlier in the introduction.

Response: We clarified in the table caption that we do not include plant mediated CH4 emissions observations as there is little data available.

RC2: Figure 2: Should that be Liu et al., 2022 instead of Liu et al., 2023? Liu et al., 2023 is not in the reference list.

Response: This was a typo and was corrected to Liu et al., 2022

RC2: L561-563: I don’t see how these numbers add up. If 46% of CO2 values were user contributed, and 50% of CH4 values were user contributed, how can the total percentage of user contributed flux observations be 41%? Shouldn’t that percentage be between 46% and 50%?

Response: This was an error in our calculations of the CO2 percentage which should be 39% and was corrected.

RC2: L595-597: Given that so many variables only pertain to terrestrial or aquatic systems, wouldn’t it make more sense to have two separate tables for this two very distinct types of ecosystems?

Response: We agreed with the reviewer and separated the dataset into terrestrial and aquatic

RC2: Table 3: Here “Aquatic” means aquatic system observed by EC? As most aquatic fluxes were observed through non-EC methods, wouldn’t it make more sense to call it “Aquatic EC”? If you have surface area for lentic aquatic systems, why don’t you have width for lotic systems? Do you really have more entries for “k600_equation” and “k600_method” than actual values for “k600” itself?

Response: In Table 3, “Aquatic” refers to all aquatic/freshwater measurements for both EC and non-EC methods. We clarified that in the caption. Unfortunately, we did not request data on the stream width. It was also not part of previous syntheses such as GRiMeDB, so that we did not include it. The width can be a very useful variable and hopefully it will be included in future releases or other syntheses, and we commented about this on line 1815.

Because we aggregated data or available data was aggregated differently than in ABCFlux v2, it could happen that a k600 value could not be attributed to the site-month, but we knew how the k600 value was determined. Therefore, it is correct that there are more entries for “k600_equation” and “k600_method” than for actual k600 values.

RC2: L672-674: If you combine “Edge” and “Center” observations, what method do you use for the weighting? Or don’t you weight and just calculate the average? Do you indicate how many values where spatially aggregated?

Response: We did not weight the observations, but rather used the average of Edge and Center if both were available, so that we stayed consistent with giving per-waterbody fluxes/concentrations. If measurements were taken on different days, the number of days when measurements were conducted were indicated. The number of individual measurements is not given in this dataset, but could be a valuable addition for a future release. We clarified this in the manuscript on lines 699-701 and 709-710.

RC2: Table 7: Here I would strongly suggest using mg C instead of g C in the units

Response: We changed the unit in table 7 as well as supplement tables 8-10 to mg C

RC2: L1409: “(Voigt, Marushchak)” You wanted to put references here?

Response: Yes, we added the correct reference here