

Dear authors.

Based on the helpful and constructive reviewer comments, I am inviting you to provide a response. I feel comments about the **database accessibility and network integration** are particularly important to ensure usability and accessibility of the manuscript. Please make sure to provide careful consideration to these.

Thank you very much.

Tobias Gerken

Dear Dr. Gerken,

Thank you for the opportunity to revise our manuscript. We found the reviewers' comments constructive and believe they have helped us improve both the manuscript and the usability of the TundraFlux Database.

In response to the comments regarding accessibility, we reviewed the repository links and data availability information within the manuscript. We updated the database file in the repository and clarified the status and accessibility of the database repository.

To address comments regarding integration with existing networks and databases, we expanded the discussion of how TundraFlux relates to other chamber-based flux synthesis efforts, including ABCFlux and COSORE, and clarified the unique scope of our database (**L173-183**). We further strengthened the discussion of expanding the scope of the TundraFlux Database beyond  $R_{eco}$  by incorporating additional greenhouse gas fluxes, such as  $CH_4$  and  $N_2O$ , as well as net ecosystem exchange (NEE) and gross primary productivity (GPP) and highlighted the harmonization of datasets and metadata standards as a key priority for future development (**L380-398**).

In addition, we incorporated several smaller revisions suggested by the reviewers, including clarifications of database structure, metadata, and future directions. Please note that the line numbers in our response refer to the manuscript version when tracked changes are accepted or displayed in "no markup" mode.

We appreciate the time and effort invested by the reviewers and thank you for handling our manuscript.

Sincerely,

Sarah Schwieger

On behalf of all co-authors

## **Reviewer 1:**

This manuscript describes the aggregation of ecosystem respiration data from air warming experiments across arctic and alpine tundra warming manipulations. Efforts to aggregate data from similar groups of experiments run by PIs distributed across institutions and nations is extremely valuable to facilitate synthesis, model comparison, and identify gaps. Thus, I think this database is a valuable contribution to the literature. There are several other chamber-based flux aggregation products which the authors mention in their next steps as a goal to facilitate integration. I believe it would be worth explicitly mentioning and distinguishing these in the introduction or description and structure sections. A few aggregated datasets of which I am aware are ABCFlux (ambient only), COSORE (global, focused on continuous, not necessarily aggregated for experimental manipulations), and the ITEX Ecosystem carbon flux dataset. Additionally, are all the sites in TundraFlux listed in Vogt et al 2025. ARGO: ARctic greenhouse Gas Observation metadata version 1? If not, adding entries there would be a good way to build on existing resources and reduce diverging aggregation efforts.

Overall, this paper is well written with informative graphics and descriptions of the data structure. I feel I have a good grasp of what I expect to find in the dataset and how it is organized.

**Response:** We thank the reviewer for their positive and constructive feedback on our manuscript and the TundraFlux database. We also appreciate the suggestions regarding related synthesis efforts and metadata initiatives.

We agree that providing additional context on existing chamber-based flux synthesis efforts helps position the TundraFlux Database within the broader data landscape. We have therefore added a short paragraph describing ABCFlux and COSORE, and clarifying how TundraFlux complements these existing resources, to Section 2.1, 'Scope and Purpose', in the 'Description and Structure' section. This paragraph covers **L173-183**:

*”Several related chamber-based flux synthesis efforts already exist, including the Arctic-Boreal Chamber Flux Database (ABCFlux; Virkkala et al., 2022), which focuses on ambient CO<sub>2</sub> flux observations across Arctic and boreal ecosystems, and COSORE (Bond-Lamberty et al., 2020), which compiles continuous soil respiration and soil–atmosphere greenhouse gas flux measurements across ecosystems worldwide. The TundraFlux Database complements these efforts by specifically compiling Reco observations from both ambient and experimentally manipulated tundra ecosystems.”*

We also now explicitly mention these databases in the discussion of future integration efforts, where it now reads:

*” Finally, we aim to link the TundraFlux Database with other available databases on terrestrial carbon fluxes (Table S1), including the Tundra Trait Team database (Bjorkman et al., 2018), the*

*Manipulation Experiments Synthesis Initiative (MESI; Van Sundert et al., 2023), COSORE (Bond-Lamberty et al., 2020), and the ABCflux database (Leffler et al., 2025; Virkkala et al., 2022). Although integration remains challenging due to differences in data formats, identifiers, and metadata standards, establishing common protocols will be crucial to advance syntheses across databases.” L390-395*

Furthermore, we added a **new Table S1** in the supplements:

**Table S1:** Comparison of the TundraFlux Database with related databases and synthesis initiatives relevant to tundra ecosystem research. The table highlights the primary scope of each resource and illustrates how TundraFlux complements existing databases by providing harmonized ecosystem respiration ( $R_{eco}$ ) observations from both ambient and warming experiments in Arctic and alpine tundra ecosystems.

Database	Reference	Primary scope / distinction
<b>Tundra Trait Team</b>	Bjorkman <i>et al.</i> 2018, <i>Glob. Ecol. Biogeogr.</i> ; <a href="https://doi.org/10.1111/geb.12821">https://doi.org/10.1111/geb.12821</a>	Plant trait database for tundra species. Contains vegetation trait information but no ecosystem carbon flux measurements.
<b>COSORE</b>	Bond-Lamberty <i>et al.</i> 2020, <i>Glob. Change Biol.</i> ; <a href="https://doi.org/10.1111/gcb.15353">https://doi.org/10.1111/gcb.15353</a>	Global compilation of continuous/automated soil respiration and soil greenhouse gas flux measurements. Emphasizes high-frequency temporal observations rather than tundra-specific ecosystem respiration syntheses.
<b>ABCFlux</b>	Virkkala <i>et al.</i> 2022, <i>Earth Syst. Sci. Data.</i> ; <a href="https://doi.org/10.5194/essd-14-179-2022">https://doi.org/10.5194/essd-14-179-2022</a>	Arctic–boreal carbon flux database containing multiple carbon flux components across ecosystems, primarily under ambient conditions. Not specifically focused on tundra ecosystem respiration or experimental warming manipulations.
<b>Manipulation Experiments Synthesis Initiative (MESI)</b>	Van Sundert <i>et al.</i> 2023, <i>Glob. Change Biol.</i> ; <a href="https://doi.org/10.1111/gcb.16585">https://doi.org/10.1111/gcb.16585</a>	Global compilation of terrestrial climate-change experiments (e.g., warming, nutrient addition, CO <sub>2</sub> enrichment). Documents experimental manipulations and associated metadata rather than harmonized tundra Reco measurements.
<b>TundraFlux</b>	Schwieger <i>et al.</i> , 2026, DOI: 10.5281/zenodo.17976235	Tundra-specific ecosystem respiration database integrating ambient and experimental warming (open-top chambers) across studies with standardized environmental and experimental metadata.

However, we are unsure which dataset the reviewer is referring to when they mention the **ITEX Ecosystem carbon flux dataset**. We assume that the reviewer might be referring to the dataset used in Maes, *et al.* 2024: *Environmental drivers of increased ecosystem respiration in a warming tundra* (<https://doi.org/10.1038/s41586-024-07274-7>). In section 3 of the manuscript, 'Applications of the TundraFlux database', specifically 3.1 'Identifying magnitude and drivers of ecosystem respiration response to warming through meta-analysis' (L266–271), we state that we

are using 136 datasets from 56 OTC experiments at 28 tundra sites worldwide. This represents 60% of the data in the TundraFlux Database. The data used in this paper can be accessed via the citation provided in our manuscript.

Regarding the representation of TundraFlux within the metadata compilation by Vogt et al. (2025) (ARGO: ARctic greenhouse Gas Observation metadata version 1; <https://essd.copernicus.org/articles/17/2553/2025/>), the TundraFlux database was not included because the dataset is not yet publicly available. However, we hope that the database can contribute to future ARGO releases once TundraFlux is openly accessible after acceptance. More broadly, facilitating integration into existing synthesis platforms and community efforts such as ARGO, ABCFlux, and COSORE is one of the key motivations behind publishing the TundraFlux Database.

### Some detailed, line-by-line comments

#### Data sources:

**Table S1:** do some of these come from databases (eg: LTER for CiPEHR and Toolik sites)? It would be helpful to add these links to the table as well. I think it would be additionally helpful to identify which of these sites originates from the establishment of ITEX.

**Response:** Thank you for this comment.

Whenever available and applicable, co-authors and data contributors were encouraged to provide links to related datasets and publications in what is now **Table S2 (previous Table S1)**. We updated the reference column with new links to datasets from Cambridge Bay and the Iceland CRUST site.

Concerning links to LTER, the CiPEHR data included in the TundraFlux Database were compiled and filtered specifically for this synthesis effort and therefore do not correspond exactly to previously published datasets available. Here, we present a subset of the data that can be found at LTER. The data we included in our database are nighttime  $R_{eco}$ , as stated in (**L235-239**):

*”All experiments measured daytime  $R_{eco}$  using dark or opaque chambers, except for the CiPEHR site in Alaska (ALA\_1), where automated chambers continuously measured  $CO_2$  respiration using clear chambers. To obtain comparable respiration estimates for this site, we extracted only nighttime fluxes, defined by photosynthetically active radiation (PAR) values below  $5 \mu mol m^{-2} s^{-1}$ , as these best approximated dark chamber conditions. These night-time measurements were therefore used as the site’s  $R_{eco}$  values.”*

We have added a link to the original, unfiltered CiPEHR data (<https://www2.nau.edu/schuurlab-p/data.html>), which can be accessed in what is now Table S2 (previously Table S1) of the supplements.

Regarding our data connections to ITEX, many of the warming experiments included in TundraFlux use open-top chambers (OTCs) and are conceptually aligned with the International

Tundra Experiment. However, because participation in ITEX is voluntary and there is no strict formal definition of membership, it is difficult to unambiguously classify sites as ITEX sites. We would therefore like to avoid making definitive classifications and instead clarify the relationship of these experiments to the broader ITEX framework where appropriate.

**Table S2:** not sure how useful Nobs is other than to show generally large vs small datasets. Instead perhaps adding the frequency/interval of measurement or mode of measurement such as manual vs automated.

**Response:** Thank you for the comment. We had indeed the intention to show the magnitude of larger vs smaller datasets within the database in this table. We now added the measurement frequency in what is now **Table S3 (previously Table S2)** of the supplements, which is estimated from the mean interval between consecutive daily averaged observations per site-year: Daily ( $\leq 1.5$  days), Weekly (2–8.5 days), Bi-weekly (8.5–16 days), Monthly (16–35 days), or Irregular ( $> 35$  days). We also added a column with the number of raw observations (N Raw Obs.) before daily averaging to show readers how many individual measurements underlie each daily average

Only one site currently has automated chambers in the database, i.e. CiPHER (ALA\_1 in our database) , which is stated in **L235-236** of the manuscript as:

*“All experiments measured daytime Reco using dark or opaque chambers, except for the CiPEHR site in Alaska (ALA\_1), where automated chambers continuously measured CO<sub>2</sub> respiration using clear chambers.”*

We have therefore not added information on the mode of measurement in in Table S3 (former Table S2).

**Table S4:** Is the Daily\_% the percent of days in a year with measurements? So 0.5% would be an average of 1.8 days of measurement over the years measured?

**Response:** Yes, we see the confusion. The “Daily\_%” column does not represent the percentage of days in a year with measurements. Instead, it reflects the proportion of total observation days contributed by each site relative to the full dataset (i.e., across all sites combined).

Specifically, we first aggregate the data to unique site–day combinations with  $R_{eco}$  measurements and then count the number of days per site. The percentage is then calculated as:

$$total\ number\ of\ measured\ days\ per\ site / total\ number\ of\ observed\ days\ across\ all\ sites \times 100.$$

Thus, the values are intended as a relative weighting of sampling effort across sites, not as within-year sampling frequency.

We changed the column name from ‘Daily\_%’ to ‘Site\_contribution\_%’ and edited the caption of what is now **Table S5 (previous Table S4)** to:

*”Table S5: Number of years  $R_{eco}$  was measured and number and percentages of total observed site–day records (i.e. summed daily observations), by site and region. “* to improve clarity.

**Use country codes that match a standard.** I believe Fluxnet currently uses: ISO-3611-2: <https://fluxnet.org/data/fluxnet2015-dataset/known-issues/>. I think using standardized names reduces guessing and makes it easier to link with other products.

**Response:** We thank the reviewer for the helpful reference and agree that standardized codes are preferable to uncontrolled country names. In our dataset, we use **ISO 3166-1 alpha-3** (three-letter codes, e.g., NOR=Norway, SWE=Sweden), which is a widely recognized ISO standard. FLUXNET uses the same standard but alpha-2, which means only two letters (e.g., NO=Norway, SE=Sweden). We think that alpha-3 codes offer a readability advantage in research contexts, as they are more immediately recognizable without requiring a lookup table. Further, since sites are linked via site IDs, plot IDs, and coordinates rather than country codes, we do not expect any compatibility issues with FLUXNET or other datasets. However, we would be willing to switch to ISO-3611-2 using the two-letter code if the reviewer or editors feel this would support wider usability of the database.

Reviewer access URL for code, readme, data dictionary did not work (page not found error from Zenodo)

**Response:** Our apologies for this inconvenience. We provide an updated link for the reviewers in the new uploaded manuscript.

**Text:**

**Line 128:** Suggestion not starting the paragraph with ‘its’. Instead something like: ‘Ecosystem respiration plays a central role... making it important to predict... ‘

**Response:** Thank you for the recommendation. We changed the sentence, it now reads:

*”Ecosystem respiration plays a central role in the global carbon cycle, making it essential to predict how  $R_{eco}$  responds to climate change. However, accurately forecasting the extent, as well as the spatial and temporal variability of these responses, remains a major scientific challenge (Karhu et al., 2014; Maes et al., 2024; Rustad et al., 2001; Schuur et al., 2022; Sulman et al., 2018; Virkkala et al., 2021).”* **L129-132**

**Line 135:** It would be useful to briefly describe the OTC method.

**Response:** Thank you for the comment. We described the OTC method in the methods in section 2.2 Data sources and data collection, but we agree, an earlier introduction may indeed benefit readers to better understand the scope of the TundraFlux database. Therefore, we moved the description to **L135-142** of the introduction, which now reads as follows:

*”Here, we present the TundraFlux Database, which contains  $R_{eco}$  measurements derived from open-top chamber (OTC) warming experiments. These experiments use small greenhouses to passively increase air temperatures during the snow-free season while allowing relatively free entry of precipitation (Hollister et al., 2023; Marion et al., 1997; Welker et al., 1997). OTCs are commonly used to simulate climate warming at a plot-scale in low-stature Arctic and alpine tundra systems, e.g., in the International Tundra Experiment network (ITEX; <https://www.gvsu.edu/itex/>; Henry and Molau, 1997; Hollister et al., 2023). These experiments provide a unique opportunity to analyse patterns and drivers of  $CO_2$  respiration under warming conditions across bioclimatic gradients, which arise from differences in climate, vegetation, and soil characteristics (Maes et al., 2024).“*

**Line 169-171:** Are these metadata time-varying if the experiment is multiple years long? Or are they site-specific and temporally fixed?

**Response:** This is indeed an important question. The metadata is site-and-plot specific but not strictly temporally fixed, and the linkage year (flux\_year) may not equal the measurement year. The metadata measurement year is not always identical to the flux year (in which Reco is measured). In some cases, the closest available metadata measurement is associated with a given flux year. In Maes et al., 2024, we assessed whether mismatching of  $R_{eco}$  with environmental driver data from different measurement years influenced the results through performing a sensitivity analysis, that is, rerunning the meta regression models on the basis of several restrictive sample size scenarios (Supplementary Fig. 4 and Supplementary Discussion 4 in Maes et al 2024).

We recognize that a dedicated metadata measurement year column would clarify this, and we have added this as the columns ‘veg\_survey\_year’ (i.e., the year in which the vegetation measurements of the ‘plant\_metadata\_plot’ dataset were taken) and ‘soil\_survey\_year’ (i.e., the year in which the soil measurements of the ‘soil\_metadata\_plot’ dataset were taken) to the database to make the temporal relationship between flux data and metadata explicit. We updated the data dictionary in what is now **Table S4 (previously Table S3)** accordingly.

**Line 232-235:** Restricting the NEE fluxes to night-time only is a reasonable approach. However, I wonder what the data source was for the CiPEHR data because Reco (extrapolated from night to day using a temperature-response function) is included in the datasets in the BNZ LTER data catalog: <https://www.lter.uaf.edu/data/data-detail/id/481>.

There are also some respiration measurements during and from the end of the growing season. Not sure if they are included?

<https://www.lter.uaf.edu/data/data-detail/id/611>

<https://www.lter.uaf.edu/data/data-detail/id/572>

<https://www.lter.uaf.edu/data/data-detail/id/652>

**Response:** The CiPEHR data included in the TundraFlux Database were compiled and filtered specifically for this synthesis effort and therefore do not correspond exactly to previously published datasets available through the Bonanza Creek LTER data catalog. In particular, we compiled only **measured ecosystem respiration data** relevant to the scope of this study and excluded modeled respiration products. Because TundraFlux integrates curated subsets and additional auxiliary datasets from multiple sources, there is not always a one-to-one correspondence between the datasets included here and externally archived products.

Regarding the datasets suggested by the reviewer, some of these measurements may overlap temporally with the data included in TundraFlux. However, our synthesis specifically focuses on ecosystem respiration measurements from open-top chamber (OTC) warming experiments, as described in **L184–186**:

*“The TundraFlux Database compiles in-situ measurements of daily-aggregated terrestrial ecosystem-level CO<sub>2</sub> fluxes (g C-CO<sub>2</sub> m<sup>-2</sup> day<sup>-1</sup>) from Arctic and alpine tundra ecosystems to assess warming effects on ecosystem CO<sub>2</sub> respiration (Reco). We compiled data from experiments that used open-top chambers (OTCs) from across the Arctic and alpine tundra biome.”*

Datasets outside this scope were therefore not included.

**Line 262:** I think this sentence has a word missing

**Response:** Yes, indeed. We changed the sentence to:

*“The TundraFlux Database is based on a global synthesis of how ecosystem respiration in Arctic and alpine tundra responds to experimental warming (Maes et al., 2024).”* (**L266-267**)

**Line 288:** perhaps cite Schadel et al 2018 Divergent patterns of experimental and model-derived permafrost ecosystem carbon dynamics in response to Arctic warming as an example?

**Response:** Thank you for pointing us towards this publication that describes the possible divergence of model results from field experiments and highlights the need to align field-based warming measurements from, for example, the TundraFlux Database with model simulations. We added it in **L292**.

**Line 295:** Remove ‘while’ to start with The TundraFlux Database? I think it’s important to point out, as you do, that the imbalance is a reflection of the field rather than a limitation of the

TundraFlux data aggregation effort. In a sense, these aggregation efforts allow us to see the imbalance more clearly.

**Response:** Thank you for pointing this out. We changed the sentence and it now reads:

*” The TundraFlux Database inherently reflects a sampling imbalance in the field, particularly the underrepresentation of key Arctic regions such as the Canadian High Arctic archipelago and Siberia (López-Blanco et al., 2024; Metcalfe et al., 2018; Virkkala et al., 2019; Fig. 1A, Table S5). Still it represents the most comprehensive effort that is currently available of Reco data from warming experiments in the tundra.” (L299-302)*

**Line 372:** and/or air vs soil warming as the CiPEHR experiments show that the effects of snow-fences carry over into the summer because the warming soil profile is cumulative. And air warming in summer can alter winter conditions as shifts in vegetation can alter soil conditions (eg: Heather Kropp et al 2021 Environ. Res. Lett.)

**Response:** That is an interesting point. We added this to the sentence, which now reads:

*” This will enable us to distinguish between the effects of summer (OTC) and winter (snow fences) warming on Reco, as well as the combined effects of these treatments (Hermesdorf et al., 2024). It will also allow us to account for cross-seasonal carry-over and the effects of coupled air-soil warming, whereby winter soil warming persists into summer and summer air warming can indirectly modify winter soil conditions via changes to vegetation (Kropp et al., 2020).” (L380-384)*

## **Reviewer 2:**

The authors present a commendable collaborative effort in integrating daily aggregated in-situ  $R_{eco}$  measurements from air warming experiments consisting of control plots and warmed plots with open top chambers at 64 Arctic and alpine tundra sites across 12 countries. The dataset spans from 2000 to 2024 and has decent coverage of circumpolar Arctic ecosystems, making it a robust resource for spatial and temporal studies. The dataset has strong potential to contribute to collaboration across nations and research teams in current and emerging studies, allowing for reliable model comparison and leading to a scalable synthesis of Arctic warming and responses in  $R_{eco}$ , and becoming a useful resource to further our understanding and identify knowledge gaps of Arctic ecosystems and biogeochemical cycling. Therefore, I think this dataset is fitting for Earth System Science Data and is a meaningful contribution to the literature. However, I found that the future directions of the manuscript were lacking, and I think the authors could be more explicit in mentioning their next steps, as well as mentioning how they will streamline the process of maintaining the database for future data integration and cross-collaboration.

Overall, the manuscript was easy to follow and is well-written. I found that I was able to have a solid understanding of what the database is and its utility. Accessing the database took me some time, but once I had downloaded all the files from Zenodo and had tinkered with them in R, I was able to view them. I appreciate the authors' organization of the datasets and files, as well as the detailed information provided in the supplementary materials. I think TundraFlux is an impressive and valuable resource, and I appreciate it being an open-access dataset.

**Response:** We thank the reviewer for their positive assessment of the TundraFlux Database and for recognizing its potential to support synthesis studies, model evaluation, and international collaboration. We also appreciate the reviewer's suggestion to provide more detail on future directions and long-term database development. In response, we have expanded the discussion of future perspectives to more explicitly outline planned database growth, including the incorporation of additional flux variables (methane and nitrous oxide) and experimental treatments, integration with complementary databases and synthesis efforts, and continued community-driven data contributions (L377-395).

**Below, I have made some line-by-line suggestions for the authors to consider:**

### **Supplementary:**

**S1:** I really liked the inclusion of the start year for each of the sites for the warming experiments. I think it would be helpful to include a column for the end year as well here, or within the same column for the start year, and change it to provide the beginning and end year (e.g., Start – End warming)

**Response:** We are glad to hear the reviewer found the inclusion of the start year of the warming experiments useful. We agree that the duration of prior warming can be an important factor, as it may influence plant and microbial community composition and thereby affect  $R_{eco}$ . However, to our knowledge all the warming treatments included here are still ongoing and therefore do not have a defined end year. We asked for this information specifically in the data collection phase

and no dataset provided an end year for their warming treatment. For this reason, an end date is generally not applicable, and we have chosen to report only the start year.

**ITEX\_biomass\_method\_protocol:** The inclusion of this document is a nice addition and a helpful resource for the database. However, it looks like the links included in the document do not work for reviewer access and received a “404 file not found” error.

**Response:** Thank you for letting us know. We have now revised the document to include only the relevant information: the protocol for plant height measurements. We have also updated the link to the ITEX manual.

## Main Text

### 1. Introduction

**Line 119:** Might want to consider including a definition for permafrost (e.g., soil that remains consecutively frozen for at least 2 years)

**Response:** We agree and added a definition of permafrost in **L117-121**, where it now reads:

*”The Arctic and alpine tundra biome stores one-third of global soil organic carbon, which is nearly twice the atmospheric carbon pool (Schuur et al., 2015), much of it locked in permafrost (i.e., soil that remains consecutively frozen for at least 2 years), organic-rich mineral soils, and peat (Gorham, 1991; Hugelius et al., 2020; Park et al., 2025; Schuur et al., 2022; Tarnocai et al., 2009; Zimov et al., 2006).”*

### 1. Description and structure

**Lines 158-164:** adding a line or two in this paragraph to mention that warming alters tundra ecosystems in the increasing frequency of thermokarst activity (geomorphology impacts), which may also contribute to  $R_{eco}$ . Some references below:

<https://www.nature.com/articles/ncomms13043>

<https://www.nature.com/articles/s41467-019-09314-7>

[https://ecoss.nau.edu/wp-content/uploads/2016/05/Vogel\\_et\\_al-2009-Journal\\_of\\_Geophysical\\_Research-\\_Solid\\_Earth\\_1978-2012.pdf](https://ecoss.nau.edu/wp-content/uploads/2016/05/Vogel_et_al-2009-Journal_of_Geophysical_Research-_Solid_Earth_1978-2012.pdf)

[https://www.researchgate.net/publication/281261197\\_Permafrost\\_collapse\\_alters\\_soil\\_carbon\\_stocks\\_respiration\\_CH4\\_and\\_N2O\\_in\\_upland\\_tundra](https://www.researchgate.net/publication/281261197_Permafrost_collapse_alters_soil_carbon_stocks_respiration_CH4_and_N2O_in_upland_tundra)

**Response:** We acknowledge geomorphological disturbance (thermokarst/permafrost collapse) as an additional warming pathway influencing tundra carbon dynamics and potentially ecosystem respiration ( $R_{eco}$ ), and have added a corresponding sentence, which now reads:

*“Warming alters tundra ecosystems through a suite of interacting biotic and abiotic pathways, including changes in vegetation composition (Bjorkman et al., 2020; Collins et al., 2021; Garcia*

*Criado et al., 2025; Wilson and Nilsson, 2009), plant productivity (Hollesen et al., 2015; Myers-Smith et al., 2019), microbial activity (Frossard et al., 2021), decomposition rates (Sarneel et al., 2020; Schwieger et al., 2025), nutrient cycling (Weedon et al., 2012), growing season length (Barichivich et al., 2013; Collins et al., 2021; Myers-Smith et al., 2019; Oberbauer et al., 1998), and snow-mediated microclimate conditions (Morgner et al., 2010; Pattison and Welker, 2014; Rixen et al., 2022), as well as increased thermokarst activity and permafrost degradation, which can strongly alter soil structure and carbon availability and thereby contribute to ecosystem respiration (Reco) (Abbott and Jones, 2015; Lewkowicz and Way, 2019; Olefeldt et al., 2016; Vogel et al., 2009).” (L164-171)*

**Line 210:** This could be a user error on my end, but when opening the Tundra\_flux\_daily\_v1 in my version of R, I see 76 variables instead of 74. Could it be a typo here?

**Response:** That is indeed a typo and we corrected it.

**Lines 258-259:** You may want to double-check to make sure the DOI works for others to access Zenodo. Additionally, having a direct link here to the dataset would be helpful to readers. Maybe this can be included in the DOI display name?

**Response:** The dataset will be made publicly available through Zenodo upon acceptance of the manuscript in *Earth System Science Data*. At present, the DOI is reserved but not yet active, and will become fully accessible once the publication is accepted. We will ensure that the final published version includes a working direct link to the dataset.

## **Applications of the TundraFlux database**

**Lines 274-275:** I appreciate the authors' efforts in including shoulder season observations in the database.

**Response:** We agree that these measurements are important for improving our understanding of ecosystem respiration outside the growing season, which remains comparatively underrepresented in current datasets.

### **1. Future Directions**

**Lines 369-379:** Would including other variables be considered for future directions in addition to what is already included in the database? For example, the tundra type or landform (thaw slumps, peatlands, coastal, etc.) for each of the sites would be interesting and helpful for future studies. Additionally, mentioning other potential methods that can be incorporated into, for example, the integration of field-based observations and remotely sensed observations?

**Response:** We thank the reviewer for this suggestion. We already include several of the proposed future directions in the manuscript, on **L377-395**. Specifically, we outline plans to incorporate additional flux variables such as methane, nitrous oxide, NEE, and GPP (**L377-378**), as well as additional experimental manipulations such as snow fence and experiments (**L379-384**). We also explicitly discuss integration with other major tundra synthesis efforts and databases.

We agree that additional metadata layers, such as tundra type, landform classification (e.g., peatlands, thaw slumps, coastal systems), and potential links to remotely sensed products, would be highly valuable for future syntheses. These are indeed important directions for improving cross-site comparability and scaling. We therefore added a sentence in the discussion highlighting these as longer-term opportunities for database development. It reads as follows:

*“In recent years, remote sensing using unmanned aerial vehicles (UAVs) and satellites has advanced significantly, providing an opportunity to quantify landscape heterogeneity in the tundra biome at high spatio-temporal resolutions (Assmann et al., 2020; Myers-Smith et al., 2020). With this data, it is possible to bridge the gap between the TundraFlux plot-scale field measurements and large-scale remote sensing mapping products. In addition, we will incorporate remote sensing-derived metadata, such as tundra type and landform classification (e.g., peatlands, thaw slumps and coastal systems), as well as other derived products (Niittynen, 2026; Virkkala et al., 2024; Wagner and Hugelius, 2026), into future syntheses. Finally, we aim to link the TundraFlux Database with other available databases on terrestrial carbon fluxes (Table S1), including the Tundra Trait Team database (Bjorkman et al., 2018), the Manipulation Experiments Synthesis Initiative (MESI; Van Sundert et al., 2023), COSORE (Bond-Lamberty et al., 2020), and the ABCflux database (Leffler et al., 2025; Virkkala et al., 2022). Although integration remains challenging due to differences in data formats, identifiers, and metadata standards, establishing common protocols will be crucial to advance syntheses across databases.” (L385-395)*