**General Responses:**

We thank the three reviewers for their comments, and those who provided community comments too. We will respond to all comments individually but there are some general points mentioned in multiple comments that we would like to address, here labelled as General Responses 1 to 3 (GR-1 - GR-3).

**GR-1**: There is some confusion as to the purpose of this work; this work is an addition to the Varved Sediments Database (VARDA) as opposed to a data compilation exercise using the database. This was not made clear within the text and in the revised manuscript we now explicitly state that this data is a new addition to VARDA (Lines 15, 18, 60, 74).

**GR-2**: The Kernel Density Estimate plots are not meant to be a comprehensive overview of all known findings of the tephra layers, instead they are intended for use as a statistical and schematic diagram to highlight the future potential to better synchronise varve chronologies using tephra layers. We hope that further clarification in the caption of Figure 4 addresses this issue.

**GR-3**: The inclusion of tephra data into VARDA is not intended to be used as a new database for tephrochronologists; we aim that the inclusion of tephra data enables varve chronologists to better synchronise varve chronologies to an absolute timescale using tephra as an isochronous marker horizon.

**Reply to Reviewer #3 (://doi.org/10.5194/essd-2023-154-RC2)**

**We appreciate the clear and constructive review by Christine Lane. Many points have been incorporated in our revised version of the manuscript or will be taken on board for future iterations of the dataset (see responses to individual comments below). We copied all comments below, numbered them in order of appearance (RC2-1 to RC2-12) and provided a response accordingly.**

**RC2 - 1**: Beckett et al. report on the addition of information about the occurrence and geochemical compositions of tephra layers within European varve sequences reported in the Varve Database (VARDA). Tephra layers offer the potential to connect varve chronologies at single moments in time with the potential to compare and transfer differential and absolute dating information between sites and increase overall dating precision by replication. The authors state the aim to incorporate information from tephra in varves globally over the coming 5 years, as well as increase the window of time for which data is included. The reasoning for the addition of tephra information is well presented in the manuscript, although as VARDA already includes relevant palaeo proxy datasets for many sites, it is unclear why this particular

"proxy" requires a stand-alone publication. The addition of the "event" layer bar in the GICC05 panel of the VARDA home page is a useful tool for quick reference however, and perhaps as the database grows it will be able to provide a useful online reconnaissance tool for project design and field site selection.

**RC2 - 2**: Whilst this paper addresses the inclusion of tephra data, I found myself browsing VARDA more generally and found myself confused by the inclusion of many non-varved lakes (I'll just note some of the ones I am familiar with as I have worked on them: Lake Victoria, Lake Tanganyika, Lake Bled). I felt a clearer description of the VARDA database itself was probably needed to make sense of the datasets entered to date.

**Authors response:** *The rationale for adding non-varved lakes was originally discussed in Ramisch et al. (2020). We do not seek to modify this rationale in our manuscript but we do acknowledge that a clear reference needs to be made to the original VARDA paper. This clarification has been made in the caption of Figure 3 with reference to the criteria set out in Ramisch et al., (2020) to include non-varved lakes with good chronological control.*

1. Significance

**RC2 - 3**: This particular compilation of tephra layers reported in varve sequences in Europe is unique in that draws together commonalities in the records and could be a great time-saver in looking up sites and articles. Highlighting the value of tephra layers to varve researchers is also beneficial. Additional value could be achieved by including specific and relevant search tools, such as those from the RESET database (Bronk Ramsey et al., 2015) that are used within the article to show the connectivity between records using tephra layers and maps (e.g. KDE) of the sites where tephra layers have been reported. The RESET database is problematic as it is no longer maintained, but in terms of a tephra data repository it is more complete and contains critical data missing from the VARDA database as presented (see comments under Data Quality). The VARDA team might be better to find a means to connect VARDA with that database, rather than starting again to record all of the published tephra layers in Europe within a new repository.

**Authors response:** *We would like to refer here to GR-3 as we do not aim for VARDA to be a new tephra repository but a database that allows varve chronologists to access the available tephra geochemical datasets specifically from varve records.*

**RC2 - 4**: One note that caught my attention was a sentence in the conclusions about the opportunity to explore machine learning approaches to tephra compositional analyses. As there is no mention of this in the body of the paper, it needs further exploration and justification.

If there are additional novel tools being created that could really add to the uniqueness and usefulness of the growing compilation.

**Authors response:** *We highlight this as a potential venture for future work that would be valuable for both the tephra and varve communities, and include it as a suggestion (Line 179).*

2. Data Quality

**RC2 - 5**: Data in VARDA is easily searched and clearly presented and downloadable. I applaud the inclusion of EPMA analytical conditions but I cannot understand the exclusion of secondary standard data, which is critical to evaluating whether one can compare to another tephra dataset or not. The authors referred more than once in the manuscript (e.g. within Table 2 that sets out mandatory and optional criteria for metadata) to the inclusion of "*Standards used for analytical calibration, e.g. Lipari Obsidian".* Two types of standards are used in EPMA work and there seems to be confusion here. Primary standards are usually a suite of minerals or oxides with known elemental compositions, which are used to calibrate the instrument. The publication of primary standard data is not conventional, as what matters is that the data is accurate, not which minerals were used for which elements. Secondary standards are materials of known composition that are analysed before, during and after a run of analyses on an unknown sample, in order to demonstrate the accuracy and precision of the calibration. These are usually matrix-matched to the material being analysed, so the Lipari Obsidian, for example, is a commonly used secondary standard for the analysis of volcanic glass. The tephrochronology community has long called for the inclusion of secondary standard analyses alongside ALL tephra compositional datasets, so that the data may be trusted to make comparisons between tephra datasets generated at different times and on different instruments (e.g. Hunt and Hill., 1996; Kuehn et al., 2011; Wallace et al., 2022). At present, I couldn't find any secondary standard data within the VARDA database, which means that if I were to use it to trace tephra layers, I would immediately have to open the original article and extract the data from there, rather than from VARDA. Those less conscientious might unintentionally propagate poor data and miscorrelations. I strongly recommend that the database authors amend the database to include *either* i. a clear statement that *only* data with secondary standards within 2 standard deviations of published assays are included in the database (a lot of work for data stewards), *or*, ii. secondary standard analyses for all tephra datasets, alongside a link to published assays.

In addition, reviewing the criteria for recording tephra geochemical data, I would recommend that data type (e.g. single grain, whole rock) and material (e.g. glass shards, mineral, pumice) are added as essential criteria. This is also essential metadata for ensuring like is being

compared with like and whilst most data will be single-grain glass shard analyses, it should not be a given.

**Authors response:** *We agree that for accurate comparisons of tephra geochemical data to be made, the secondary standard data needs to be readily available; in this current phase of work, we comment on the need for this data to be included in the next iteration of data to be added to VARDA (L.104). We are aware that secondary standards remain an issue as some information from older papers and projects do not report the analytical totals for secondary standards. We would in the next phase of data collection, aim to include this information which is available for roughly half of the sites mentioned in this article. We will clarify in the text that we are referring to the secondary standards on line 104, which refers to future additions on the database. At present it is our view that users of VARDA should refer to the original papers for secondary standard totals. Future iterations will follow the guidelines set out by Wallace et al. (2022).*

*We renamed the column "standard" to "secondary_standard" in the supplemented data, worksheet "Datasets", and added short references where possible. The columns "secondary_standard_reference_1" and "secondary_standard_reference_2" are added, containing DOI links to the primary references for secondary standards. We added the column "material" to individual samples in the worksheet "Tephra_Major_Elements" and a column "material_description" in the "Datasets" worksheet (supplementary metadata) for a basic classification of the sampled material. We will provide material information in higher granularity in the next iteration of tephra data collection..*

Minor editorial notes

**RC2 - 6**: Title: I would focus here on European and LGIT tephra data in varve records as the potential and value of a global inventory isn't obvious from the article and data at this stage.

**Authors' response:** *We acknowledge that this has been picked up by both reviewers and have made a change to the title, but we feel that clarifying the intent of the paper to provide an update to VARDA helps to solve this issue as it is a global database and this is the first phase of adding to the inventory.*

**RC2 - 7**: Abstract: There is inconsistent use of capitalisation and hyphenation in "last Glacial-Interglacial transition" between the paper title and the abstract that needs correcting one way or the other.

**Authors' response:** *The capitalisation was unified to "Last Glacial-Interglacial Transition" in the title, abstract and text to be consistent with Timms et al. (2019).*

**RC2 - 8**: Introduction, Line 39: the term "well defined" needs explaining.

**Authors' response:** *We agree that the term 'well-defined' is vague in this sentence and have sought to clarify this in the revised article (Line 42) .*

**RC2 - 9**: Methods, Line 73 and 98/99: References to standards used for calibration, rather than secondary standards, needs correcting.

**Authors response:** *This has been corrected in the text (line 76, 104).*

**RC2 - 10**: Figure 2 and 3: Bled, Ohrid and Prespa (at least) are not varved and their inclusion needs an explanation. If non-varved lakes are included, then what do we get from VARDA that is unique? There are asterisks noting that Ohrid and Prespa are non-varved in Fig 3, but not Bled. Other sites I am less familiar with.

**Authors response:** *As previously explained in our response to CC1-2, the inclusion of some non-varved sites is outlined in the original VARDA paper (Ramisch et al., 2020). We do, however, agree that Bled should also be highlighted in this article as not containing varves and have adjusted Figure 2 and 3 to reflect this..*

**RC2 - 11**: Results, lines 126 and 133: The Mediterranean does not describe a volcanic region and it would be better to define to at least Italian and Hellenic Arc, if not specific volcanic fields.

**Authors response:** *We agree with this comment and have made the appropriate changes to reflect a more accurate volcanic origin (Lines 131 and 139).*

**RC2 - 12**: Line 151: I would replace "tephra plume" with "tephra fallout area" to avoid any indication that the sites studied faithfully capture the plume dispersal of an eruption. This is especially pertinent given that within the screen shot of Askja-S sites, Iceland (therefore the volcano) is not included in the shaded envelope.

**Authors response:** *We agree that "tephra plume" may lead to a misinterpretation of the eruption dispersal. According to this suggestion, "tephra plume" was replaced by "tephra dispersal" in 4. Implications (lines 155 and 159).*