

## Authors' response to review of “DebDaB: A database of supraglacial debris thickness and physical properties”

We would like to thank the two reviewers very much for their careful and very useful reviews, which have contributed to substantially improve our manuscript. The main points in the reviews were:

- Suggestion to change the database acronym (RC1)
- Suggestion to remove the analysis linking debris properties from lines 205-210 and Fig. A2 (RC1)
- Inclusion of a discussion on the variability of methods and associated uncertainty was missing (RC2)
- Remove discussion of regional differences, as the dataset is too small to infer regional differences in debris properties (RC2).
- Change the way we refer to the fitted lines in Figure 4, which are technically not Østrem curves as they omit the rising limb of ablation rate (RC2).

and we have addressed them all. As a result, we have implemented the following main changes:

- Our new proposed database acronym is DebDaB (with capital B).
- We have removed the analysis related to former Figure A2.
- We have written a new subsection (4.3) on variability of methods.
- We now make it clearer that regional differences are most likely due to sampling biases.
- We have modified the term “Østrem curves” to “simplified Østrem curves”.

We have also revised the terminology as suggested by Reviewer 1 (and now include when referring to debris properties the terms “layer” or “bulk”), and implemented all other minor suggestions (see below). We have also included some additional datasets, and in particular the thermal conductivity values from Romshoo et al. (2024) (pointed out by a community comment)

We are thankful for such constructive and thoughtful reviews and hope the editor and reviewers will be satisfied with our revised manuscript. We find it much improved.

In response to the editor and to adhere to the open source data policy of Earth System Science Data, the revised version of the database (v2) is now provided in an open-source document format (Open Document Spreadsheet, .ods), and as a geopackage (.gpkg). Additionally, each debris property is provided as a separate .csv file too. We also now provide the templates for data submission as .csv files.

We provide our detailed responses to the two reviews below, point by point.

In black: reviewers' comments

In blue: authors' response

## **1. Referee Comment 1: 'Comment on essd-2024-559', by Morgan Jones**

### **Review of DebDab: A database of supraglacial debris thickness and physical properties**

#### **General comments:**

The manuscript presents an extensive dataset of supraglacial debris properties, compiled into a database. The database is an important and valuable contribution to the research area of debris covered glaciers, as nothing on this scale has existed previously. It will be an excellent resource to which data going forward can be added to.

Generally, the manuscript is largely well written and presented clearly and logically, with useful figures and tables. There are a few minor issues, detailed below, which are provided to enhance the flow of the paper and to clarify some aspects.

The data files are easily accessible, well presented, clearly organised and sufficiently explained for publication. I think it is great that templates for submitting data are provided, as combining data into a database is often time consuming due to variations in their presentation.

I do suggest the title 'DebDab' is replaced with 'DebDB' as DB is the common acronym for database, and thus makes more sense.

In conclusion, I think this manuscript is publishable following minor corrections.

Dear Dr. Morgan Jones,

Thank you for your time and the careful and extremely useful review of our manuscript. We are happy you find the dataset an excellent resource and valuable contribution to debris-covered glacier research, and we thank you for the comments to improve the manuscript. We essentially agree with all your suggestions for improvement, and we have revised our manuscript to include them all.

Regarding the suggestion to rename the database title to "DebDB" instead of "DebDab", we have adopted an intermediate name: "DebDaB" (with capital B). We acknowledge that DB is a more common acronym for database, but we also find "debdab" an appealing and pronounceable acronym, which we believe will make communication and visibility of the dataset name easier.

Regarding the rest of textual suggestions and corrections, we have incorporated them all and you can find a response and action taken point by point below.

#### **Specific comments:**

Line 4: Suggest 'supraglacial debris' is changed to 'supraglacial debris layer' to be more specific, as the properties collated into the database are debris layer properties rather than individual clasts.

We find this suggestion very appropriate, as we agree that most data in DebDaB concern the entire supraglacial debris layer or the bulk properties of the layer, instead of individual clasts. We have adapted the terminology throughout the manuscript (e.g. lines 4, 5, 7, 52, 62, 78, 81... in the author's track changes manuscript).

Line 6: Suggest 'has not been published before' is changed to 'are previously unpublished'.

Done.

Line 10: Suggest replacing 'for the' with 'to'

Done.

Line 11: Suggest replacing 'DebDab' can be used' to 'The data within DebDab can be used'

Done.

Line 17: Suggest replacing 'the entire manifestations of debris across elevations' with 'debris properties for all elevations'.

Done.

Line 18: Suggest replacing 'DebDab is an openly available dataset that aims at evolving and being updated with' with 'The aim of DebDab, as an openly available dataset, is that it evolves over time and is updated and added to through'.

Done.

Line 25: Suggest that '(1-2 centimetres)' is updated to '(less than around 2 cm)' or '(less than a few centimetres)', as a thin debris layer can be less than 1 cm thick, and the threshold varies from the glacier to glacier, so is not as specific as currently stated.

Changed to "less than a few centimetres".

Line 26: Suggest replacing 'and thicker debris reducing it by' with ', whilst thicker debris reduces melt by'.

Done.

Line 36: Suggest replacing 'insufficient' with 'limited' so the former is only used once in the sentence.

Done.

Line 45: Suggest replacing 'as measurements' with 'as collecting such/these measurements'.

Done.

Line 46: Suggest replacing 'often involve' with 'are often'.

Done.

Line 48: Suggest replacing 'may be' with 'is'.

Done.

Line 54: Suggest adding 'into one database' after 'properties'.

Done.

Line 56: Suggest replacing 'for the scientific community for their modelling' with 'for use by the science community to support and enhance numerical modelling'.

Done.

Line 62: The use of 'the debris' is somewhat vague here and throughout the manuscript. I suggest replacing with 'the debris layer' or 'the bulk debris layer' throughout to show you are considering properties of the bulk debris layer.

Revised throughout the manuscript (e.g. lines 4, 5, 7, 52, 62, 78, 81, in the author's track changes manuscript).

Line 71: Suggest replacing 'due to its' with 'through'.

Done.

Line 73: Suggest removal of 'the' before 'melt'.

Done.

Line 80: Suggest replacing 'or' with 'which is'.

Done.

Line 93: Suggest rewording 'can range from 20% to 60%' to 'has been found to range from 20% to 60%' or including '~' before each value. It is unlikely these values are absolute thresholds.

Done.

Line 94: Suggest including '~' before the values in 'from 40% at the surface to 20%'. It is unlikely these values are absolute thresholds.

Done.

Line 101: Suggest replacing 'with increasing debris cover area' to 'as the proportion of the debris covered glacier surface increases'.

Done.

Line 103: Suggest replacing 'above' with 'Section 2'.

Done.

Line 106: Suggest removal of 'a compilation of'.

Done.

Line 109: Suggest removal of 'over' before hundreds'.

Done.

Line 110: Suggest addition of 'provides a' before 'citation'.

Done.

Line 142: Suggest replacing 'debris thickness values are provided in metres, surface roughness length in metres' to 'debris thickness values and surface roughness length are provided in metres'.

Done.

Line 144: Suggest replacing 'As detailed data descriptions as possible are included in the database' with 'The data descriptions provided in the database are as detailed as possible'.

Done.

Line 147: Suggest replacing ‘. The dates of the measurements’ with ‘Dates on which measurements were collected’.

Done.

Figure 1: Figure 1 should be placed under the text in which it is introduced (Section 4.1.).

Done.

Line 165: Suggest replacing the second ‘information’ with ‘provided’.

Done.

Line 169: Suggest replacing ‘show a high variability’ with highlight the variability’.

Done.

Line 175-176: Suggest capitalising ‘region’ in all cases.

Done.

Figures 2 and 3: These plots could be combined into one figure, so they are easier to view together.

Done. This is now Figure 2, and all later figures are one number lower.

Line 189: Suggest ‘very similar’ is replaced with ‘near to’.

Done.

Line 190: Suggest replacing ‘that (Brock et al., 2010) provide and that’ with ‘that Brock et al. (2010) calculated, which’.

Done.

Line 192: Suggest adding ‘which is apparent’ before ‘despite’.

Done.

Line 205-210, Figure A2: I do not think this analysis is particularly useful, and the paper would not lose anything if it was removed. Variability in debris properties can be big over the chosen arbitrary distance of 10m, and will vary between glaciers and at different locations on a glacier. I suggest removal of this analysis.

We agree that the analysis in Lines 205-210 and Figure A2 does not add much to the manuscript and the presentation of the dataset. Our intention was to find links between debris properties but agree that this is out of the scope for this paper, and since the dataset is still of limited extension, this was inconclusive and we found no relationships within the data presented. We have removed it in the revised manuscript. We have instead added a sentence in section 5.1 (potential applications, lines 305-306 in the author's track changes manuscript) indicating that when more fully populated, the database could form the basis for investigating relationships between debris parameters.

Line 215: Suggest replacing ‘properties in’ with property values within’.

Done.

Line 215: Suggest including ‘constraining’ before ‘energy’.

Done.

Line 227: Suggest replacing ‘around  $\pm 10\%$ ’ with ‘varying values by up to’.

Done.

Line 228: Suggest addition of 'available' before 'in DebDab'.

Done.

Line 233: Suggest adding 'and compared to existing data' before 'to understand'.

Done.

Line 239: Suggest replacing 'provided by' with 'available in'.

Done.

Line 243: Suggest replacing 'once more data' with 'as more data become'.

Done.

Line 25: Suggest addition of 'Consequently,'.

We are not sure exactly for which line this suggestion is, as one digit is potentially missing. We are happy to accommodate this edit after some more guidance from the reviewer.

Line 264: Suggest replacing 'This shows that for the middle segment of the glacier in particular debris thickness measurements are undersampled' with 'Consequently, these results highlight that there is a lack of data available for the middle segments of glaciers'.

Done.

Line 265: Suggest 'These are' with 'The middle glacier area'.

Done.

Line 280: Suggests removal of comma.

Done.

Line 281: Suggest replacing 'despite the strong efforts in collecting as much data as possible, and as detailed as possible' despite the effort to collate as much detailed data as possible'.

Done.

Line 282: Suggest replacing 'have escaped the data collection of' with 'were not available for inclusion in'.

Done.

Line 285: Suggest including 'for it; between 'is' and 'to'.

Done.

Line 285: Suggest replacing 'updating' with 'being updated'.

Done.

Line 288: Suggest replacing 'These data can then on a yearly basis be included into an updated version of DebDab.' With 'These data can then be included in future updated versions of DebDab'. This change is suggested so the authors are not tied to a specific schedule of updating!

We appreciate this suggestion and have incorporated it.

Line 295: Typographic error in 'gran.

Done.

Line 307: A comma is suggested before and after 'r such as North America and South America'.

Done.

Line 308: Suggest replacing 's from the upper reaches' with 'from the middle and upper reaches'.

Done.

Line 332-333: Suggest commas are adding in the following places for this sentence: 'Some regions, such as South Asia East and West, show consistently thicker debris than other regions, such as Central Europe or Alaska.'.

Done.

Line 333: Suggest the addition of 'the production of' between 'enables' and 'an'.

Done.

Line 337: Suggest replacing 'for any use of the dataset' with 'when using the dataset'.

Done.

## **2. Referee Comment 2: 'Comment on essd-2024-559', by Anonymous Referee #2**

### General Comments

Modelling the surface melt rate and mass balance response of debris-covered glaciers to a changing climate is an ongoing challenge in glaciology, with particular issue being the limited knowledge of physical and thermal properties of debris and their variability in space and time. The open publication of the DebDab database is therefore extremely welcome and timely, and will provide a valuable resource for cryospheric scientists, and water managers and users in glacierised mountain regions. The high level of usage DebDab will receive is evidenced by >250 downloads and addition of new datasets already since its publication on Zenodo late in 2024.

Although, 90% of the dataset has been published before (10% is new data, previously unavailable) it has been compiled from 172 publications, representing a considerable research effort. Certain sources may be inaccessible to some scientists due to paywalls, and in cases data and clarifications were obtained through personal communications to the authors. As the authors note, some of the key debris parameter values used in model studies tend to come from the same 1 or 2 publications, and DebDab will provide scientists with a better understanding of their variability and what may be a suitable parameter value for a specific glacier environment.

DebDab is easy to access and download (as an Excel workbook), and I found it very easy to navigate and use. The amount of supporting information is impressive and adds value. In addition to the value of each debris property, for each entry there are up to 29 further columns of information, such as the geographical co-ordinates, collection method, descriptive statistics, source reference, and notes. The database contains additional supporting metadata 'read me' files, a list of publications and templates for uploading new datasets.

The debris physical parameters included in DebDab (thickness, thermal conductivity, surface roughness, albedo, emissivity and porosity) are the key ones needed, since debris extent in space is relatively well known having been mapped from satellite. DebDab is also likely to be

of value in improving the delineation of areas of debris-covered ice in debris cover products. The dataset is complete in terms of being compiled from an exhaustive search of available published (and some non-published) sources but will be added to over time as a central repository for results from future field and remote sensing investigations. Most of the published sources do not give extensive consideration to errors but often this is because the measurement technique is not sophisticated. For example, the majority of debris thickness measurements are from physical excavation and a measuring stick. The greater uncertainty is due to the spatially limited, and spatially biased, sampling of debris properties which are nicely highlighted and discussed in the article. I should make clear this is not the fault of the authors, or a limitation to the database. Indeed, DebDab should serve as an inspiration to the community to agree on measurement standards and encourage targeted campaigns using direct, geophysical and remote sensing techniques to improve knowledge of supraglacial debris properties and their variability.

The article is well written and structured, and of appropriate length and detail to support the database. The language is concise and clear, with accurate and high-quality figures and tables. Mathematical formulae, symbols, abbreviations, and units are generally correctly defined and used. The presentation of the data is consistent and some helpful general analysis and visualization is presented as an overview of the data. I particularly like Figure 6, and similarly, Figures A4 and A5. There are a small number of presentation issues to address as detailed in the “Technical corrections and typographical errors” section below.

In summary, DebDab is a substantial, unique and high-quality dataset, and the authors must be thanked for their considerable effort and dedication to bring this information together in an intuitive, easy to use and ‘living’ database. It will provide the community with a valuable resource for decades to come and I am sure it will get plenty of use.

Dear referee,

Thank you for your positive and encouraging review of our manuscript. We are pleased to see that DebDaB is well received by the scientific community and that it will be useful for and used by scientists. We agree with your point that certain data in DebDaB may have remained hidden because the publications that describe them are not open access, even if the data themselves are. Your review has undoubtedly helped us improve our manuscript, and it encourages us to keep the database alive and evolving.

Specific comments

1. The only area where the authors may wish to consider some additional discussion in their manuscript is in the consistency of the data. Debris thickness, thermal conductivity and surface roughness values were obtained through different methods by different workers. While this is acknowledged in DebDab, identification of issues with individual methods, such as potential errors or issues of quality control, would be of benefit to users. Are there examples of more than one method being applied and achieving similar values at the same site, which would lead to confidence in the result?

This is a very good point, and **we have added a new subsection titled “4.3 Variability of methods” describing the variety of sampling and measuring methods for each debris property**, which was lacking in the manuscript and offers useful material for reflection on past, current and future measuring efforts. In the same spirit, **we have also added a discussion sentence about the uncertainty associated with the variety of methods applied by different data collectors** (lines 345-350 in the author's track



changes manuscript). DebDaB has gone through a curation and quality control check, but the different methods could lead to further uncertainties that may remain unnoticed by the user. Even with simple measurements like manual excavation for debris thickness, procedures may slightly differ per data collector.

2. Line 174-177, the dataset is too small to make inferences about debris thickness differences between regions. Rarely are measurements of sufficient spatial coverage and density to derive statistical descriptors for a single glacier, let alone a region. Make the point that the regional differences more likely reflect biases in sampling rather than actual differences.

This is also an excellent point, and the reviewer is right that regional differences could simply be due to biases in sampling. In fact, our lines 309-316 in Section 5.2 (limitations) describe these sampling biases in more detail. **We have mentioned this after the old lines 174-177 (see lines 194-195 in the author's track changes manuscript) and also referred the reader to Section 5.2 for further discussion.** Furthermore, **we have added the number of measurements per region together with the boxplots in Figure A1, to highlights the different number of measurements per region.**

3. Lines 179-186, Figure 4, Table A1. The fitted curves are not true “Østrem curves” as they omit the rising limb of ablation rate for very shallow debris up to an “effective thickness” (Adhikary et al., 1997) which was identified by Østrem (1959) and most subsequent studies of ice melt rate dependency on debris thickness. Fitting curves to very thin debris is clearly difficult with limited measurements, but I think it is important to identify this omission from Figure 4 and the ablation rate-debris thickness equation, as its application could lead to overestimation of ablation in very thin debris areas.

It is true that the curve we fitted is not strictly an Østrem curve but a rational curve. However, the term has been used in the literature also for curves without that component of the melt response to thickness. **We have specified throughout the manuscript that these are simplified Østrem curves**, in the form of a rational curve, depicting the declining limb of melt with debris thickness only (see lines 199-201 in the author's track changes manuscript **We have also added a discussion** sentence indicating that application of this curve can lead to unrealistically high melt rates for very thin debris (see lines 199-201 in the author's track changes manuscript).

4. Section 5.1. Another application could be to detect changes in debris properties over time particularly in the 21<sup>st</sup> century as glaciers rapidly shrink. Repeated measurements at glaciers with large numbers of measurements could be important in determining trends in debris properties to inform models of glacier evolution at multi-decadal and longer timescales.

We agree this is a great potential application, and thank the reviewer for suggesting it. We very briefly mentioned this in potential applications and in priorities for future measurements, but we have now made it clearer (line 295 in the author's track changes manuscript).

Technical corrections, typographical errors

Regarding the technical corrections and typographical errors: we agree with them all and have implemented the changes in the revised manuscript. See a point by point action below.

Line 33, clarify that in the term ‘glaciers’ you are excluding the Antarctic and Greenland Ice Sheets (while glaciologists are familiar with this distinction, the definition will help scientists

from outside this community who may wish to use the dataset).

Added “(in the current study excluding the Antarctic and Greenland ice sheets)” in lines 33-34 in the author's track changes manuscript. However, we state now in “Future developments” that the database is open to inclusion of data from debris-covered glaciers in Antarctica and Greenland, if available (line 371).

Line 154, “thicknesses” or “thickness measurements”.

Done.

Line 196, “...the 0.016 m, also from Brock et al. (2010).”

Done.

Line 209-210, also point out that in some cases linear fits have been applied to non-linear relationships, e.g. panel A2(c).

We have removed Figure A2 and its associated text (lines 205-210 in the initial submission manuscript) as per the suggestion of Reviewer 1.

Figure A2 – check the consistency in terminology, e.g. debris thickness is  $h_d$  on panels a, b and c, but DT on panel d. On panel (f) the vertical axis units should be Emissivity (dimensionless). By convention in bivariate relationships the y-axis variable depends on the x-axis variable and should be the first property in the sub-panel title. This is done correctly for panel (j) “Porosity vs Emissivity” but incorrectly for the other panels.

We have removed Figure A2 and its associated text as per the suggestion of Reviewer 1.

Line 271, “...the number of measurements is much lower.”

Done.

Line 295, replace “gran” with “grain”.

Done.

Line 298, I don't think “meteodata” is a commonly used term, if you mean “meteorological data” please state this instead.

Changed to meteorological data.

Lines 312-314. I think the correct reference here is Brock et al. (2010). This study's debris thermal conductivity value was calculated as the mean of 25 distributed measurements so perhaps it is not so coincidental that it is similar to the mean thermal conductivity of all measurements in DebDab.

Indeed it is Brock et al. (2010). We agree it might not be so coincidental, but in fact it is interesting that the mean thermal conductivity of 25 measurements in one same glacier (Brock et al., 2010), is similar to the mean thermal conductivity of DebDaB measurements, which contain measurements across glaciers and across regions. We have slightly rephrased this in lines 390-391 in the author's track changes manuscript.

Lines 332-333, please state again that this difference could be due to sample bias.

Done.

## Reference

Adhikary, S., K. Seko, M. Nakawo, Y. Ageta and N. Miyazaki. Effect of surface dust on snow melt. *Bulletin of Glacier Research*, 15, 85-92, 1997.

### **3. Community Comment 1: 'Incorporation of thermal conductivity values available for other glacier(s) in Zanskar, Ladakh Himalaya (Region 14)', by Basharat Nabi**

The paper provides detailed and valuable information on supraglacial debris. However, the authors should include available thermal conductivity values for glaciers in the Zanskar region of the Himalaya. A relevant reference for this data is the study by Romshoo et al., 2024 titled "Influence of Debris Cover on Glacier Melting in the Himalaya", published in Cold Regions Science and Technology (2024). The authors may find it useful to incorporate insights from this paper (DOI: 10.1016/j.coldregions.2024.104204) to strengthen their discussion on the thermal properties of supraglacial debris.

Dear Dr. Basharat Nabi,

We appreciate your feedback on the paper and your suggestion to include thermal conductivity values from the study by Romshoo et al. (2024) in the Zanskar region in the Himalaya, and we thank you for making those data available through your manuscript. We have incorporated the thermal conductivity values into DebDaB version 2 and we now refer to the paper you suggested. Indeed, we find the discussion in Romshoo et al. (2024) about the estimated thermal conductivities useful, and we find it interesting that the calculated values of 0.9 and 1.1 W/m/K fall exactly within the mode range of thermal conductivity values in DebDaB (see Figure 5a).

This is exactly the type of feedback we would expect from the community to expand the database and make it a living, evolving tool, and we thank you for starting this already during the review process.

**Response by Basharat Nabi in interactive discussion:** Thank you for your response. In addition to considering the thermal conductivity values in Fig. 5a, please include this value in Fig. 3 as well, specifically for region 14.

**Further authors' response:** Thank you again for your comment. Indeed the manuscript figures have been updated in the revised manuscript together with the release of version 2 of the database, which include these data.