Author Response to Reviewer #2.

The comments by Reviewer #2 are in black. The author's responses are in blue. The changes suggested to the revised manuscript are in green.

Anonymous Referee #2

Referee comment on "Retrogressive thaw slump theory and terminology" by Nina Nesterova et al., EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-2914, 2024.

As review 2, who was asked and accepted late, I both have read the manuscript and review 1. In my review I try not to repeat many of the comments from review 1, which all are valid, and I totally agree with those statements.

I was very interested in the title and the importance of RTS in a time of permafrost degradation and thaw, making these landforms a very visible witness of climate change. While acknowledging the attempt to review these features, I struggle with the paper outline and writing. The following issues arise, partly also mentioned by reviewer 1:

We would like to express our gratitude for taking the time to review our manuscript and providing feedback and suggestions to improve its quality! We have worked on rewriting the paper to address the main issue of the clarity and understandability of the manuscript.

1. The paper first introduces RTS incl. history (chapter 1), then it defines RTS (chapter 2) and describes common morphological features (chapter 3), while the discuss two divergent views of RTS, starting again with an historical background (chapter 4). This is confusing, and should be changed before publication, and I do not follow the motivation to structure the paper like that. I would recommend moving parts of the "historical background" into the start of the review, maybe into the Introduction. For a review paper this is an interesting knowledge to start with.

We fully agree that the current structure may appear confusing. To address this issue, we have restructured the paper in a way that should be easier to follow:

1 Introduction
2 Observed characteristics of retrogressive thaw slumps
- 2.1. Morphometry and dynamics
- 2.2. Position and topography
- 2.3. Ground ice
- 2.4. Triggers
- 2.5. Polycyclicity
- 2.6. Concurrent processes

We have moved the part about the historical roots of the terms (previously called "Historical background") to the Discussion under 4 Discussion → 4.1 Divergent terminologies, where we explain in detail the origin of existing disparate terms. Thus, the figure "The chronology of the usage of different terms by selected most cited authors in the 20th century…" is also moved there. Moreover, we enlarged the Introduction, including some additional historical background (particular changes in bold):

"<…>**Historically, RTS research started with the first mention of exposed ice in a retrogressive thaw slump probably dates back to 1881 by Dall in his publication on observations in Alaska (Dall, 1881) The first intensive studies on RTSs were conducted much later in the latter half of the 20th century in Canada (Lamothe and St-Onge, 1961; Mackay, 1966; Kerfoot, 1969) and Siberia (Popov et al., 1966; Czudek and Demek, 1970). These studies on RTSs were field-based and focused on ground ice, morphometry, and dynamics. The publications were written either in English or Russian language with different terms applied to these landforms depending on scientific approaches. Unfortunately, the level of knowledge exchange and reciprocal citation among RTS researchers from Canada and the USSR was relatively low, leading to the establishment of disparate views and terminology for RTS used in the literature.**

The strong rise in scientific exchange and international collaborations at the end of the 20th century, including joint expeditions within the permafrost community in general and within the topic of RTS in particular (i.e., Vaikmäe et al., 1993; Ingólfsson, and Lokrantz, 2003; Are

et al., 2005), as well as the emergence of remote sensing methods substantially broadened the scope of RTS research (Romanenko, 1998; Lantuit and Pollard, 2005; Lantz and Kokelj, 2008; Leibman et al., 2021). Today, a large body of recent literature predominantly focuses on monitoring RTS activity by measuring retreat rates (Kizyakov et al., 2006; Wang et al., 2009; Laccelle et al., 2010) and volume changes (Kizyakov et al., 2006; Clark et al., 2021; Jiao et al., 2022; Bernhard et al., 2022), identifying driving factors (Harris and Lewkowicz, 2000; Lacelle et al., 2010), or more generally mapping of RTSs (Pollard, 2000; Lipovsky and Huscroft, 2006; Khomutov and Leibman, 2008; Swanson, 2012; Segal et al., 2016). Recent publications on RTS mapping notably shifted away from a focus on geological and geomorphological aspects to developing advanced methodologies of RTS detection and classification using spatially and/or temporally high-resolution remote sensing data and digital elevation data, frequently employing artificial intelligence methods (Huang et al., 2020; Nitze et al., 2021; Yang et al., 2023).<…>"

2. The authors should review the common knowledge and discuss divergent views in a discussion chapter (which now is short and not really a discussion) or focus the paper on the different views in Russian and American literature as an example of divergent views, and come with recommendation on a common strategy. Now, the study is neither of those two.

Thank you for pointing this out. Since we aimed to review the observed characteristics of RTSs and the terminology used in the literature, we restructured the paper the way that Section 2 "*Observed characteristics of retrogressive thaw slumps"* presents the observed and described properties of RTS mentioned in the literature. Section 3 "*Terminologies used in the literature*" presents the terms (and their definitions) used in the literature to describe the naming of "*3.1. Morphologic parts*", "*3.2. Landforms*" and "*3.3. Formation process*". The Discussion Section presents an in-depth discussion on the origin and some particularities of "*4.1 Divergent terminologies*", also "*4.2 Overlap in terminologies*" and "*4.3 Limitations of divergent terminologies*". The Discussion also consists of the recommendations for the future definition of the RTS term in the next IPA Glossary ("*4.4 RTS definition in the Glossary*") and suggested term for the feature that missed the naming in the literature ("*4.5 Missing terminology*").

3. Because of that the paper is very hard to follow, the start of the manuscript is chopped in few descriptive chapters of landform details without illustration (move Fig. 1), incl a large table (maybe better off in an appendix). The second part is interesting incl. figure 3 is kind of illustrative, but is bot clearly connected to the first part.

We hope that restructuring the paper in the way described above will enhance the clarity and readability of the paper which consists of two separate parts: descriptive (observations) and definitions (terminology) parts followed by the discussion about terminology. Moreover, we

have added a figure with photos of RTSs in different regions of the Northern Hemisphere to the Introduction part for a better visual understanding of the described phenomena and their variability.

4. Concerning the discussion around landform and process, it reminds me a bit around discussion related to other landforms, such as rock glaciers, which is not always fruitful. In my understanding is RTS as term is similar to e.g. debris flow, this means a landslide process resulting in a landforms, which shape differs related to setting geological material the process is happening.

We thank the reviewer for this comment. We find the need for a critical unbiased review of the existing terminology related to RTS phenomena to avoid misunderstanding and misinterpretation of the landforms, features, and direction of the process. We have elaborated on the importance of the clarifications and discussion as well as the practical implementations of different terminology in the text of the Introduction (particular changes in bold):

"However, despite the increasing number of studies and strongly rising interest in RTS among the permafrost and remote sensing research communities, there is still no commonly agreed terminology on the RTS phenomenon. Various authors apply different terminology to describe the same morphology and processes or use the same terms for different processes. T**his leads to several difficulties in communication about RTS within and across research communities. First of all, since the terminology is not always clearly defined or translated in the literature it can lead to potential misunderstandings about what exact features or processes have been investigated in a particular study. The confusion about the object of the study may cause incomparability of the datasets from different RTS studies. Furthermore, different labeling of the same features may result in a completely different image of the phenomena. For example, Nitze et al. (2024, in review) conducted an experiment where 12 domain experts from different countries manually mapped RTSs in Canada and Russia. The results demonstrated a large mismatch of the RTS labeling in Yakutia, Russia, which can be partially explained by different terminology used in the publications describing this region. The confusion in the terminology and labeling of RTSs can also affect the related studies on how RTSs impact hydrology, geochemistry, and ecology or their physical modeling, which is based on the established terms and concepts in the literature.**

This work aims to provide clarifications on the existing terminology of RTS phenomena and ease the understanding of published studies. The paper presents commonly observed RTS characteristics and a neutral review of existing RTS terminology in the literature. Our review considers a broad variety of RTSs in the Northern Hemisphere."

Do a thorough check of the references, e.g. Yershov (1998) in line 308 is not in the reference list. But I did not check everything here.

Thank you for noticing this issue! We have performed a thorough check and added 3 references that we forgot to put in the list and corrected the years in the other 3 references.

Precise language is important in review papers, as also review 1 mentioned. E.g. l. 135 makes no sense if the list all aspect instead of writing that "there is no preferred slope orientation". Also check definitions, e.g. you use the for me unknown term "baydzheraks" in l. 151 before you define it in chapter 3.5.6.

We fully agree with the importance of the precise language. To address this issue, we have reworded several statements as requested by Reviewer 1 and added the definitions in the first place, for example:

"For example, RTS forming in syngenetic ice-rich Yedoma deposits with polygonal ice wedges are usually accompanied by the presence of **baydzherakhs** (conical remnant mounds, for details, see Sect. 3.1.6) on the slump floors."

"• the growth of a **debris tongue** (thawed sediments in a shape of a tongue, for details, see Sect. 3.1.8) can eventually obstruct a stream valley and lead to the increase of stream base level and further thermoerosion that can erode and expose the ground ice (Kokelj et al., 2015)."

We have omitted the list of slope aspects:

"**RTSs occur on a great variety of slope aspects.** While some studies investigating different regions across the Arctic reported that their observed RTSs tended to have different prevailing slope orientations (Kokelj et al., 2009; Lacelle et al., 2015; Jones et al., 2019; Nesterova et al., 2021; Bernhard et al., 2022), several other studies found that higher RTS ablation rates and headwall retreat (see Sect. 3.1.1) are related to southern aspects (Lewkowicz, 1987a; Grom and Pollard, 2008; Lacelle et al., 2015). However, several other studies did not find any link between the slope aspect and RTS activity (Wang et al., 2009; Nesterova et al., 2021; Bernhard et al., 2022). Bernhard et al. (2022) suggested that differences in the RTS aspect may be explained by regional geological history that defines ice content and ice distribution, which are the main factors of RTS occurrence (Mackay, 1966; Kerfoot, 1969)."

I really recommend a manuscript like this, and if thoroughly revised I am confident it will be read, commented and cited.

We would like to thank the reviewer once again for the valuable comments aimed at strengthening our manuscript!
