

Dear Reviewer,

We appreciate your detailed comments on the preprint (in black). We believe that your contribution will lead to improvement of the quality of our manuscript. Please find our detailed response to your comments below (in green).

General comments:

This study is an ambitious and laborious task mostly based on combination of bathymetric data sets of different resolution supported by data from earlier offshore studies and “onshore literature”. Approaches to utilize increasing amount of high-resolution bathymetric data are crucial to promote scientific discussion on the distribution of submarine glaciogenic features and the influence of sea-bed bedrock/topography on glacial dynamics, especially in the case of streaming ice. The manuscript will add to progress in numerical modelling of the Scandinavian or Fennoscandian ice sheet.

In general, structure and proper length of the manuscript make it easy to crasp. However, the major problem with the manuscript is the quality of the mapping procedure with some likely misinterpretations or lack of alternative explanations in the presented data, as also indicated by Greenwood et al. in their interactive comments. Moreover, like commented by Greenwood et al., the use of geological maps for coastal periphery-offshore interpretations would have increased the quality of the methodological approach. Uncertain observations on maps should be better presented/visualized and reasoning/data behind some interpretations, regarding f. ex. moraine landforms, should be better explained. It is important that the results and “dynamic history of the Baltic sector of the SIS” presented in Figure 8 are based on “solid” ground. Nevertheless, it is likely that some mistakes or misinterpretations remain in these kinds of maps based on large data sets with varying resolution. To sum up, the results presented in the manuscript do not convincingly enough support the interpretations made. I think the manuscript should be published after major revision, answering to above-mentioned main concerns (as also interactively commented by Greenwood et al.), and including reevaluation of some key observations or interpretations pointed out in the specific comments.

The idea of mapping procedure is to map as many features as possible to build a larger story – from single landform to flowset, to single ice stream, to particular margin, to retreat pattern, etc. We agree, that in some cases our final database of mapped features still contains some mistakes. But the biggest advantage of the mapping approach is that even if we lose one piece (misinterpreted landform) the other pieces show us the final puzzle image/story. Our mapping includes 22,500 features, and so even if there are a few mistakes (a natural consequence of large-scale mapping – no one will be 100% correct), we still believe the conclusions hold. We were not aiming for ‘definitive geological survey standard’ mapping, but rather to gather enough information to act as a basis to build information about ice flow and ice margins. Indeed, we note the recent publication of Greenwood et al. (now online in press, *Boreas*) - although these papers proceeded entirely independent of each other, it is apparent that there is a very large degree of similarity in the findings. Thus, we believe the landform misinterpretations are more technical problems that do not substantially affect the main conclusions of our paper.

We provide some arguments for our interpretations in replies to Greenwood et al. comments to preprint, but we agree that we can add alternative explanations where interpretations are less certain. In general, our conclusions are consistent with Greenwood et al. (now online in press, *Boreas*) and we acknowledge some misinterpretations e.g., diorite dyke and esker, we could fix in a revised version. The important conclusions we found are e.g.: (i) evidence for narrower corridors of fast ice flow that we interpret as distinct and smaller ice streams instead of 300-km wide zone of accelerated ice; (ii) episodic rather than steady ice retreat; (iii) our mapping identifies flow and ice marginal geometries from both Swedish and north Bothnian sources. These are not the issues obtained from analysis of single landform, and their detail geology, but a regional scale overview of landform distribution and their aggregation into flowsets, margins and patterns.

Please see also replies to Greenwood et al. comments to preprint.

Specific comments

Title: the title is ok but not very “selling” in terms of the glacial dynamics or methodology used.

Our proposition is to change the title from “Evaluation of the role of the Baltic depression during deglaciation of the last Scandinavian Ice Sheet; a landform-driven investigation” to “Evaluation of the role of the Baltic depression in controlling the dynamics of the last Scandinavian Ice Sheet; a seabed and coastal landform-driven investigation”

L_16 (Abstract): ... “that might have resulted in rapid collapse of this ice sheet sector.” <> possible rapid collapse of the ice sheet is not discussed in the main text – it should be removed from the abstract or discussed!

Agree with that. Will be removed

L_37: I would not use the term conduit here, very broad ‘channel’ is simple enough.

Agree.

L_38: it would be relevant to include information/references on the shifting ice-divide along the Scandes mountains and its probable influence on the ice dynamics!

Agree. Our proposition is to add reference to Boulton et al., 1985; Kleman et al., 1997; Patton et al. 2016.

L_39: you should maybe use more accurate definition here (unconsolidated). There is also different behavior/effect of soft sediments, depending on their composition and grainsize distribution.

Agree. Unconsolidated is better.

L_41-42: “impeding water evacuation from the ice margin” <> not from the ice-margin but from the proglacial basin?

Agree.

L_53: I think this research question is not really relevant here, the Baltic depression surely had an overall, prominent role for LGM position but related details are more poorly known + in the end you also answer first to the second question which apparently is the main issue.

Agree. Could be removed.

Table 1: Feldens et al., Dorokhov et al., Schäfer et al., Jensen, All et al. and Jakobsson et al. 2016, 2020 are not mentioned/cited in the text. If these studies are important for the landform interpretations, they should be mentioned!

Agree. Appropriate references will be added.

Figure 2: “No submarine evidence was available at the time Boulton et al. (2001) drew the figure and it is a purpose of this paper to seek information about the footprint of this ice stream and its likely width.” <> this sentence is simply well put and would be good to replace it into the introduction as well?

Agree. Will be added to introduction.

L_125-130: “Our motivation for mapping the coastal periphery of the Baltic is twofold:

1. It eases integration with the much-studied onshore landform record,

2. To provide a high-resolution verification for ice-flow patterns and ice-marginal retreat patterns mapped from the lower quality and resolution bathymetric dataset.

◁ would it be better to place this text into Methods?

Agree.

L_142: zones of soft sediment (similar consolidation or properties?)

Unconsolidated is better.

L_144: could these fan-shaped belts be indicated on a map?

Agree. Probably best place to add them would be Fig. 1

L_146: soft sediments has been found ... ▷ does this mean that elsewhere in the basin there are no soft sediments?

“The accumulation of soft sediments ...” could be changed to “The accumulation of soft sediments has been found to especially correlate...”

L_151: cross-checking ▷ this is a bit unclear way to express this – where there always hydroacoustic or seismic data available for artifact recognition? – somehow related to works presented in Table 1?

Reference to Table 1 should be added here. Cross-checking was possible when hydroacoustic and seismic data was available, not for every artifact. Sentence should be rephrased.

L_157: Mapping was carried out ... ▷ in this case the use of geological maps to verify interpretations (where possible) would have been necessary. It is important to include information from geological maps to methods as it likely strengthens the interpretations along the coastline-offshore regions. Also Greenwood et al. raise this point in their interactive comments!

We agree with that. Please see our reply to the Greenwodd et al. comments to preprint.

Table 2: for the future work, in case there are changes to databases, it would be good to indicate the date when the data was collected (f.ex. 02/2023)

Agree.

L_168: you mean glaciolacustrine wedges, please explain the term shortly when mentioned for the first time.

Yes. Glaciolacustrine. “(ice-lake contact depositional wedge-like fan)” could be added.

L_170: tunnel valleys ▷ do these include possible (braided) subglacial meltwater routes or corridors not strictly classified as tunnel valleys? See possible route in Fig. 3B just below the text: good quality DEM?

No. Our tunnel valley mapping does not include these features.

L_179-180: “identifying larger features in these regions including moraines, ice marginal channels, and ice marginal deposits was often still possible” ▷ what are these interpretations based on? – any references/supporting earlier data or just interpretation based on ...?

This sentence will be rephrased to include information that interpretation was possible for landforms where the size of the landform is greater than the resolution of the DEM and is visible in these data (e.g. due to hillshade angle, z-factor, color palette), profiles or other studies indicating the landform are present.

Figure 3: 3C) offshore area west of the Gdansk Bay has been mapped to show marginal meltwater channels (Fig 4) <> why not longshore structures (bars & troughs) related to a large spit-platform?

The profiles correspond more to marginal meltwater channels than to longshore structures. The scale of longshore structures vs. resolution of available DEM make the recognition of longshore structures difficult. Marginal meltwater channel interpretation is in accordance with meltwater routes indicated by Uścińowicz 1999 with seismic profile not directly on those landforms but present nearby. But, the smaller features could be changed to speculative meltwater channels.

L_200: remove likely

Agree.

Figure 4: would it be possible to explain in the text why there are so little landforms within the offshore areas located SW and NE from the Landsort Deep?

We agree that reader would benefit from such information. Our proposition is to add such information to the figure caption. Small numbers of landforms coincide with the presence of hard bedrock.

L_232: Fig. 5B <> where are ribbed moraines in this figure? - wrong fig?

Ribbed moraines are located in NW part of the figure. We should add this reference inside the figure.

Figure 5G: these landforms are not presented on a map!

Agree. We should correct this.

L_261: (Fig. 7E) <> I think that this ice-marginal moraine interpretation is not well justified - any reference from earlier marine investigations or reasoning behind the interpretation?

This area is poorly investigated. However, one of the moraines at Southern Middle Bank is present in the profile by Uścińowicz 1999 (Fig 5). The distal part of the moraine is interpreted as a glaciofluvial delta. We should add this reference to the sentence in L261, as follow:

Prominent end moraines are found throughout the study region including the central Baltic where they are up to 30 m high and 45 km wide (Fig. 7E). Uścińowicz (1999) interpreted the central feature from Fig. 7E as glaciofluvial delta.

L_267: (Fig. 7D) <> in this figure?

Should be 7E. Label with Słupsk Bank should be added to the figure.

L_268: distinct (?) + inferred (Fig. 7E), with <> I can't see this in Fig. 7E

Flow directions are indicated in Fig. 7E by black arrows.

Figure 6B: the leftmost flowset probably has a wrong arrow direction

No, it is correct. The lineations indicate ice flow from the north toward the south.

L_301: geological structures <> can you be a bit more precise?

We think geological structures is fine.

L_308: "Iceberg pits are identified in one locality" <> any reference for the interpretation, what is this interpretation based on?

The landform interpreted as iceberg pits are about 100-200 m long with amplitudes c. 1.5 and 2 m. Often the distal side is higher than the proximal side (with regard to inferred ice flow direction; see Fig

7D). Potentially they can be interpreted as push mounds. Such an interpretation is also consistent with the glacial context of the area (see next comment).

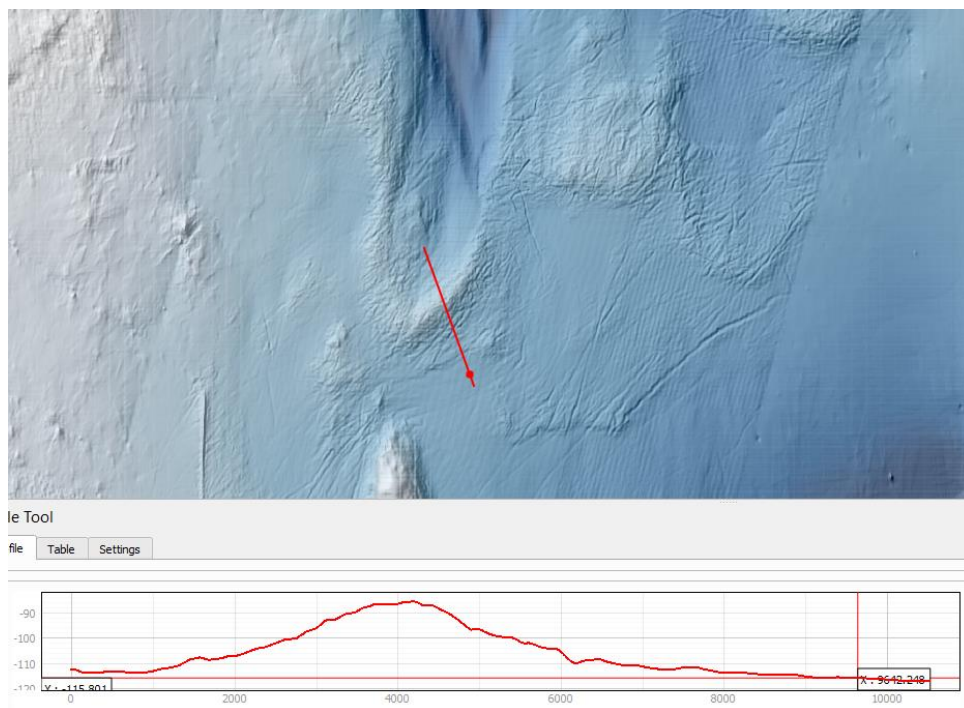
Figure 7D: I'm not convinced that these are glacial lineations! - too non-uniform + winding/overlapping - for me these landforms rather resemble submarine erosional/depositional features by bottom currents!

We agree, that the presented linear features are a combination of erosion and deposition (some above some below the bottom surface). They also overlap each other from three directions, more or less NE-SW. The study of Kramarska (1998) indicates the geology of the structure as of various origin including glacial. It is true that the topmost layer of the southern margin (about 5 km) of the bank comprises Littorina sands (till below). However, the study only loosely corresponds with the lineations, both topographically and by location. The lineations are present up to c. 40 km from Kramarska's (1998) data and profiles. The elevation of the lineations is 5 m lower. Please notice, that in Kramarska's (1998) C-D profile (p. 281) the top of the till layer occurs at ridges, like in our case. These ridges are not a product of sea currents activity. Most of the lineations are located on a lower terrace similar to that of the elevated terrace of the Odra Bank from Kramarska (1988) study, so it is highly probable that the topmost layer of the lower terrace comprises sediments that are buried in the upper terrace. The features have a positive topographical expression (contrary to negative examples from Kalmar in Fig. G from Greenwood et al. comments to preprint), and there are also iceberg pits present on top of the lineations. So, we prefer to keep our interpretation that these linear features are of glacial origin.

However, taking into consideration the 'waviness'/overlapping nature of the features presented in our study we can add that more detailed analyses are needed to clearly determine the origin of these landforms.

Figure 7F: why are these interpreted as moraines, any earlier supporting data?

An ice margin is interpreted to be at this location according to the study of Noormets, & Flodén (2002b) and their seismic profiles. The DEM is of good quality in this location. Notice in Fig. 4 that there are lots of moraines forming a group in this part of Baltic. There are MSGs not far away at the proximal side. Additionally, the profiles are consistent with moraine profiles:



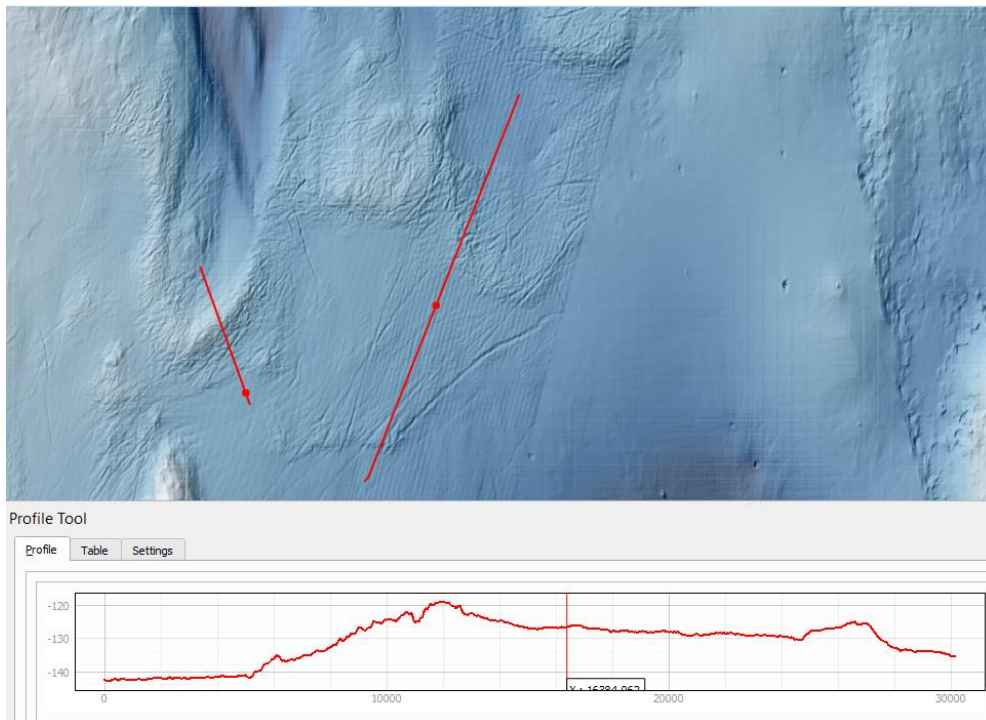


Figure 8: although there likely will remain some erroneous interpretations/details of landforms in this massive data set, this figure (black lines) should stand strong on hard evidence or if black lines are based on uncertain or extrapolated data, they should be marked with f.ex. dashed lines

In our opinion the landforms classification into two groups i.e., certain and uncertain landforms gives sufficient insight into uncertainty. Adding additional gradation of uncertainty to landforms derivatives would not help to build more advanced interpretations.

L_403: 9B <> not shown in the figure

“glaciolacustrine wedges” reference should be added to Fig. 9B

L_405-406: “An example of this is in Pomeranian Bay where a glaciolacustrine fan is overprinted by long cross-cutting MSGs, indicating a subaquatic origin.” <> sorry, but I do not understand this sentence (or reasoning), and how does it relate to previous sentence. MSGs refer to ice flow over the wedges BUT I think these MSGs are not glacial features at all but instead submarine current structures!

Sentence should be changed to “An example of this is in Pomeranian Bay.”

L_416: prominent moraines <> based on what? - any other supporting data than DEM interpretation?

Part of prominent moraines are supported by study of Uścińowicz (1999).

L_427: (Figs 8F, I; <> wrong figure reference

Agree. Should be Figs. 7F, I

L_436: outwash fans <> these not mapped in the present study?

The outwash fans from this sentence refers to the study of Noormets and Flodén (2002b) not to our mapping that do not identify outwash fans.

L_437: moraine interpretation based on what?

This interpretation is based on the DEM (expression of the landform and its context) and supported by Noormets and Flodén, (2002b)

L_450-452: “We confirm this Bothnian ice source from the north, but also identify a Swedish ice source with a ~NW-SE orientation based on our ice marginal and flowset geometries (Figs 6, 8, 9C).”
<> just to check this - are you absolutely sure that you are the first ones to report this Swedish ice source in this area?

We are pretty certain, although we checked only English written literature. In fact Noormets and Flodén (2002b) state that area north of Gotska Sandon was an inter-stream area separating ice lobe located in the Landsort Deep from that in the Faro Deep. They however do not mention that each had a separate source. A Swedish ice source can be implicitly deduced from their study.

L_457-458: Bedforms within the Landsort Deep are not presented on map in Fig 4! The Deep is an interesting and outstanding submarine geological feature, so it would be good to discuss its origin (+ references) - could there be any alternative explanation for the features interpreted here as glacial lineations?

Agree. We should comment more on this point. Our opinion is that this interpretation has a strong basis. Considering the quality of DEM (Fig 5G), context (associated moraines and nearby inter-stream supported by Noormets and Flodén (2002b)), sediments (partly coinciding with glacial clays) and geology (pre-Quaternary sandstones contrary to surrounding hard bedrock supported by All et al. (2006)) these can be interpreted as glacial features. Greenwood et al. (in press now, Boreas), independently, also interpreted these landforms as glacial lineations.

Technical corrections

We thank the reviewer for going through the manuscript in detail and indicating technical corrections which we think should be included in text.