Dear Reviewer 1,

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 improved version of our manuscript has some changes in landform mapping, slight changes in margin and flowset positions according to geological maps we consulted and a newer version of EMODnet 2022 implementation in mapping process. However our approach was focused on geomorphological expression of landforms not on their surface geology e.g., if the ridge met the requirements of moraine ridge (fan shaped, perpendicular to the ice flow direction and, in ideal situation, associated to other landforms) even if it was covered by e.g., marine sand it was classified as a moraine. 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 have now seen 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 distribution, pattern and classification of landforms. Thus, we regard the stated landform misinterpretations were more technical problems and that do not substantially affect the main conclusions of our paper, and which we retain.

We included also more alternative interpretations and refereed to the earlier studies on glacial landforms along Baltic Basin. We added also more details into the *method section* to explain some details of our approach. In our revised version we replaced *moraines* by 'ice-contact landforms', that include moraines, ice-contact fans and grounding zone wedges, and expanded their interpretations referring to some examples. Palaeoglaciologically it means an ice margin lay here without us having to intrepret the exact process that formed the landforms. This resolves the classification problem raised by referees.

Specific comments

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

The final proposition is: *Reconstructing dynamics of the Baltic Ice Stream Complex during deglaciation of the Last Scandinavian Ice Sheet*.

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!

Removed.

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

Agree, changed.

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!

We add reference to Boulton et al., 1985; Kleman et al., 1997; Patton et al. 2016:

Ice dynamics and changes in ice flow direction were also linked to ice divide shifting from the Scandinavian mountains to over the Bothnian Basin (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.

Changed to unconsolidated.

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

Agree, changed.

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, 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, 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, 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, moved to *methods*.

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

Changed to unconsolidated.

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

They are added as a result of our mapping in Fig. 4 and following Figs, however indicated by lines to minimalise uncertainty effect due to DEM resolution.

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

Changed to: Accumulations of unconsolidated glacifluvial and glacial sediments particularly correlate with the position of sills and banks (Kramarska, 1998; Lemke and Kuijpers, 1995; Obst et al., 2017; Uścinowicz, 1999; Noormets and Flodén, 2002a).

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?

Changed to: Artifacts are common in the dataset (see e.g., Fig. 3B) and its cross-checking was possible when hydroacoustic and seismic data (Table 1) were available.

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!

Done.

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, done.

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

Changed to broader term ice-contact fan.

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?

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 ...?

Changed to: However, it was often possible to detect larger features in these regions when the size of the landform was greater than the resolution of the DEM and by investigating multiple variants of hill-shade angles, z-factors, colour palettes, terrain profiles and comparing them with available studies (Table 1).

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 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 Uścinowicz 1999 with seismic profile not directly on those landforms but present nearby. We changed smaller features to speculative meltwater channels.

L_200: remove likely

Done.

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?

Added to the text: The densest concentration of glacial lineations were mapped in Landsort Deep, where they are oriented N-S and NW-SE, with the latter being more dominant. They occupy pre-quaternary sandstones, contrary to surrounding hard bedrock to the north, east and west (All et al. 2006).

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

Indicated in Fig.

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

Added.

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?

Changed to: The most prominent ice-contact landforms are found in the central Baltic where they are up to 30 m high and 45 km long (Fig. 7E), with steep proximal and gentle distal slope. The only information on their sedimentological composition comes from limited seismo-acoustic profiles, which indicate that landforms are composed of till and glaciofluvial sediments (Uścinowicz 1999). The cross-profiles combined with the shallow water in the region during deglaciation (Fig. 7E) indicate these are not grounding zone wedges but ice-contact fans.

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

Changed to 7E and a name Słupsk Bank added to Fig.

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

Thank you! Yes, changed.

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?

Removed from our mapping.

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 added more text and classified them as uncertain:

The lineations are interpreted to be glacial in origin, but with low confidence given their waviness and overlapping nature. They could also be formed by bottom currents or a mixture of glacial and non-glacial processes (i.e., exposed by erosional activity of bottom currents). Klingberg and Larsson (2017) identified lineations eroded by currents west of Öland Island, however they are clear erosional landforms with an anastomosing pattern of grooves and irregular shape (changeable width and general geometry) of 'positive' sections. MSGLs in Pomeranian Bay (Fig. 7D) have more or less the same width along the whole profile and a regular shape. They have a potentially erosional and depositional origin as the ridges clearly overlap each other from different azimuths, and they represent positive and negative landforms. In the vicinity (point 1 in Fig. 1B) there are ridges composed of glacial till with lineation-like cross profiles (Kramarska, 1998), buried in postglacial sands. Further detailed studies are required to confidently interpret the landforms in Pomeranian Bay.

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. There are MSGLs not far away at the proximal side. The landform the most to the left has typical appearance for moraine. The others could be as grounding zone wedges, with typical gentle proximal and steep distal slope.

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 (black) and uncertain (gray) landforms gives sufficient insight into uncertainty. Adding additional gradation of uncertainty to landforms derivatives would not really help in our opinion.

L_403: 9B <> not shown in the figure

Reference added to Figs 7D, 9B.

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

Changed. We also added alternative explanation and are now more speculative regarding their origin as you suggest so we present them on Fig. 4 as uncertain.

The lineations are interpreted to be glacial in origin, but with low confidence given their waviness and overlapping nature. They could also be formed by bottom currents or a mixture of glacial and non-glacial processes (i.e., exposed by erosional activity of bottom currents). Klingberg and Larsson (2017) identified lineations eroded by currents west of Öland Island, however they are clear erosional landforms with an anastomosing pattern of grooves and irregular shape (changeable width and general geometry) of 'positive' sections. MSGLs in Pomeranian Bay (Fig. 7D) have more or less the same width along the whole profile and a regular shape. They have a potentially erosional and depositional origin as the ridges clearly overlap each other from different azimuths, and they represent positive and negative landforms. In the vicinity (point 1 in Fig. 1B) there are ridges composed of glacial till with lineation-like cross

profiles (Kramarska, 1998), buried in postglacial sands. Further detailed studies are required to confidently interpret the landforms in Pomeranian Bay.

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

Changed to ice-contact fans based on steeper proximal and more gentle distal slope, the size and lithology provided by Uścinowicz (1999).

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

Thanks ! Agree, changed to Fig. 7F.

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).

L_437: moraine interpretation based on what?

This interpretation (the westernmost) is based on the DEM (expression of the landform and its context) and their unconsolidated nature is supported by Noormets and Flodén, (2002b). The other are marked as grounding zone wedges.

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 deducted 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?

Our opinion is that this interpretation has a strong basis. Considering the quality of DEM (Fig 5G), context (continuation of glacial lineations further south 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. (2023 Boreas), independently, also interpreted these landforms as glacial lineations. The lineations are presented in Fig. 4.

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.

Technical corrections:

Technical points are corrected. Some more details are given below.

Figure 1: index map is of slightly poor resolution and the scale bar is missing from the main Figure 1B.

Resolution of Fig. 1 was slightly improved. However, the only higher resolution fig. is available as supplement S1. Scale is added.

Figure 1D: could the two troughs of Gotland Island be indicated on the NW-SE profile?

Done.

L_74: 1.1 <> should this rather be 2 Background?

Done.

Figure 4: use of colours for the lines is problematic even for slightly red-green blind reader (like me). In addition to colours also different line styles could be used to clarify visualization. Figure 4: “Light and dark grey indicate onshore and offshore areas respectively” <> I think this should be the other way around

With implementing dotted or dashed lines we will lost legibility, as some lines are very short. We changed colour of eskers to differentiate them from red moraines, for red-green blind readers. We think that the mapping for the main study area (Baltic Basin) is better visible on lighter background. For those not familiar with the Baltic Sea localisation, we provided Fig. 1 with details of the study area.

Figure 8: Again, in addition to colours, different line styles would improve readability! f.ex. uncertain observations could be marked with dashed lines? In southern Sweden there is one black line containing two different retreat directions? + Scale bar is missing!

With implementing dotted or dashed lines we will lost legibility, as some lines are very short. Two overlapping margins were separated.

Best regards,
Izabela Szuman-Kalita,
Jakub Kalita,
Christiaan Diemont,
Stephen Livingstone,
Chris Clark,
Martin Margold

Dear Reviewer 2,

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

General comments:

This study is ambitious and the specific topic is highly relevant for the glacial dynamical development of the Fennoscandian ice sheet. The manuscript is of a suitable length and its structure is proper, making it easy to crasp. However, I agree with the comments of the anonymous referee and interactive comments by Greenwood et al. The mapping procedure quality issues (misinterpretations), lack of use of geological maps and the need for re-evaluation of some interpretations cause a need for major revisions.

The improved version of our manuscript has some changes in landform mapping, slight changes in margin and flowset positions, according to geological maps we consulted and a newer version of EMODnet 2022 implementation in mapping process. However our approach was focused on geomorphological expression of landforms not on their surface geology e.g., if the ridge met the requirements of moraine ridge (fan shaped, perpendicular to the ice flow direction and, in ideal situation, associated to other landforms) even if it was covered by e.g., marine sand it was classified as a moraine. 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 have now seen the recent publication of Greenwood et al. (2023, Boreas) - although these papers proceeded entirely independent of each other, it is apparent that there is a very large degree of similarity in the distribution, pattern and classification of landforms. Thus, we believe the landform misinterpretations were more technical problems that do not substantially affect the main conclusions of our paper, and which we retain.

We also included more alternative interpretations and refereed to the earlier studies on glacial landforms along Baltic Basin.

Specific comments:
(in order to minimize duplication, I will mainly comment only those points not mentioned by Greenwood et al. or Anonymous referee).

L25 (Abstract): "…broad changes in ice flow geometry, ranging from SE-NW to N-S and then to NWSE."
<> Ice flow direction replacing ice flow geometry? And maybe with description of the flow areas, for example: SE-NW in the western (SW of Malmö) area.

Finally, we decided that indication of each area is too broad as for the abstract (there are over 70 flowsets) and so describing all the areas is out of the abstract scope.

L139_L146: terminology to be clarified: The unconsolidated sediments versus sedimentary rocks. Also it is unclear what is meant with "soft sediments"

Agree, changed to unconsolidated when writing about sand and till, and sedimentary rocks when relevant.

L150: Elevation data => Bathymetric data?

Changed.

L205: Soft sediment => unconsolidated sediment?

Changed to '…soft sedimentary rocks and imprinted on thin drift..'

Technical corrections:

L77: "…from the south…"=> from towards the south
L134 and L138: "…north-western Baltic…" and "…SE Baltic…" => north-western Baltic main basin and SE Baltic main basin?

Changed

Figure 3B and 3D: conglometare => conglomerate (Is there a better word, for example bathymetric data type margin etc.?)

Changed to DEM stitching boundary

L429: could passed => could have passed

Changed.

Best regards,

Izabela Szuman-Kalita,
Jakub Kalita
Christiaan Diemont
Stephen Livingstone
Chris Clark
Martin Margold