General comments:

This manuscript presents a novel model of shear-margins, designed to be applied to specific field sites in order to gain insights into the physical processes governing the shear-margin location at the specific site. A key strength of the manuscript is the clear step-by-step method, demonstrated by an example, for how to apply the model to specific field sites. This guidance makes that manuscript particularly valuable to the scientific community, with the potential for a strong uptake of Ortholine as a tool used in future studies. Moreover, the model achieves a good balance between being simple enough to be usable and complex enough to capture the physical processes of interest. Therefore, I commend the authors on their work and recommend the manuscript for publication. I have only a few minor comments.

Specific comments:

Abstract: I suggest making it explicitly clear which of the physical processes listed can be assessed by Ortholine.

Model description:

The following aspects of the model should be clarified.

- Hardrock vs. sediment: I would like to see the distinction between the hardrock and sediment cases clearer in the model description (2.1 Governing Equations). I also suggest adding a brief description/comment in this section about how the two regions are practically included in the model, i.e. that the regions of hardrock and sediment are determined by observations.
- Please add some comment/justification of why advection of heat is neglected (in eq. 8), and the impacts of this. It would be natural to do this in lines 368-370, where the authors already mention that advection of cold ice is necessary for come physical explanations.
- Line 114: I think some explanation of how “the location of these transition points depends on the integrated force-balance of the ice stream” would be beneficial.
- Line 116-117: What happens when the melting point is reached in the model? Does melting occur at the bed/englacially? Is there then a water content? If so, what is the equation for this? Please add some explanation. Related to this, I have concerns about the Neumann condition (eq. 10) being applied in regions where the bed is temperate, in which case a Dirichlet condition T=T_m would be appropriate, with the geothermal heat flux instead going into calculating a melt rate. Perhaps these issues are addressed by the numerical optimisation method – I am not sure. Please comment on these points.

- Line 272-273: Which parameter value in the model is adjusted to increase the till strength to represent frozen conditions? The sediment cohesion c? What are the parameter values used and how are these determined?

- I find the section talking about the overburden pressure, pore pressure, basal strength and their relations (i.e. how the effect of overburden on the hydrological system is captured – line 287 onwards) somewhat confusing. I think the following could be clarified:

    - Should line 288 say "function of effective pressure", rather than "pore pressure"? \tau_c in eq. 32 is a function of \rho g H – p, i.e. the effective pressure, and in the end the pore pressure is removed from eq. 32, so I think the term "pore pressure" in the quote above could cause confusion. I think it should also be made clearer how exactly the choice made in eq. 32 captures the effect of overburden pressure, i.e. is it through making \tau_c a function of effective pressure, or through taking the pore pressure to be a linear function of overburden, etc.?
    - Related to this, in eq. 32, the substitution p(y) = k_p \rho g H(y) is made, but this is done without explanation. I think a statement is needed to say that this substitution is made, as well as an explanation of why the pore pressure is taken to be a linear function of H. Line 303, which quotes eq. 32 as where the pore pressure is taken to increase with overburden, could also be modified.
    - Line 304: "linearly varying bed strength" – perhaps saying "linearly varying bed strength in H", or similar, would be clearer.
    - Line 313-314: please provide details of how k_p is fitted, and perhaps mention when k_p is first introduced (in eq. 32) that is a parameter that will be fitted.

Notation:

- I find the use of u and v in the minimisation slightly confusing, with reason for using one of the two symbols over the other not always being clear. I suggest that the authors clarify the meanings of u and v and use these consistently throughout the manuscript. For example, perhaps it would be clearer to use u in eq. 13, as is done in eq. 12, but making clear that the solution of eq. 12 and 13 is u = v. Similarly, why is v use in eq. 27 but u used in eq. 28?
- A second point on notation is that I suggest using a different symbol for the elements and element area, instead of \tau, since \tau (although with a different

subscript) is also used to represent the shear stress, with some equations featuring both uses of \tau.
- In e.g. eq. 12 and 16, I suggest adding a small space between \alpha and u to make it clearer that it is sin(\alpha) x u, not sin(\alpha x u).
- When the discretisation is introduced to the energy functionals in eq. 20, 23, and 26, I think it would be more appropriate to use a “approximately equal to” sign.
- The driving force f is defined differently in line 168 and line 266, with the latter but not the former containing a H. Please make these consistent.

Figures:

- I think many of the figures would benefit from being a page or so later in the manuscript, to better match up with the text, but this is something to be addressed in the final version of the manuscript.
- Figure 2: I think the figure could be made clearer by adding an arrow to indicate the flow direction, and adding a title to each of the diagrams: “Previous models” and “Ortholine”.
- Figure 4: I suggest adding a key to the plot so that the colours are not necessary to identify the lines (e.g. when looked at in greyscale).
- Figure 5: I suggest joining together the two arrows that form the corner arrow to make a single cornered arrow.
- Figure 6: Perhaps consider including an arrow to indicate the flow direction.
- Figure 8-10: Some details are missing from these figures: the symbol \tau_b for the basal strength, a label for the colour bar, and, in fig. 10, the axis labels in b3. I also recommend using different shades or red and blue for the sliding coeff. and basal strength, because the two colours currently look the same in greyscale.
- Figure 8: Consider changing the scales in a3, b3 so that it looks visibly like the sliding coefficient is ‘high’ in both segments at the western shear margin in b3, rather than it appearing that the two segments are more similar in a3.

Other:

- Line 197-198: I would consider rewording the final sentence, because it makes it sound like Schoof (2006b) used discretisation parameters, but the start of the paragraph says that Schoof (2006b) provided an analytical solution.

Technical corrections:

Line 56: typo: “heterogeneous (and) basal condition”

Line 120: typo: “equivalent minimising” -> “equivalent to minimising”

Lines 131-132: replacing the commas with hyphens would make the sentence more readable.

Line 134: typo: “minimisations” -> “minimisation”

Fig. 3 caption: separately -> sequentially (otherwise it makes it sound like there is absolutely no dependence of one on the other)

Line 168: “J_c(v_i)” -> “Since J_c(v_i)” and “and” -> “it” (to avoid starting a sentence with mathematical notation).

Line 238: typo: “orto-flow”

Line 363: “with a meltwater channel within can” -> “containing a meltwater channel can”

Line 423: lower case “d” in “Despite”

Line 435: brackets in the wrong places in the citations

Line 450: missing space after the second citation

Line 452: “five key steps” -> “four key steps”