This manuscript explores fjord circulation in proglacial fjords with an extensive set of numerical simulations. The study focuses on the impact of a sill in driving reflux _ an exchange from the outflowing layer back into the deeper inflow, which impacts the fjord circulation patterns, heat content, stratification, and – in some way – the heat transport to the glacier that drives melt (though as outlined below, this last point is the weakest part of the paper). The authors identify 4 different regimes based on the relative depths of the fjord, sill, and plume, which is an important step towards mapping out the parameter space of different fjords around the globe. Overall, the paper is well-written with clear figures and interesting results. While I have several major comments, I think these are addressable and this paper is well on its way to being a valuable contribution to the literature on ocean-glacier interactions in fjords.

Major Comments

1) Heat transport, heat budgets & melting. In my view, the parts of the paper requiring most attention (or cutting) are the aspects related to heat transport and melting. The paper tries to evaluate parameters that affect the "heat transport to the glacier" and thereby submarine melt rates. But there seem to be multiple, intertwined points of confusion about heat budgets and melt rates.

The primary "heat transport" calculations are reported in Table 2, as the "heat flux" in the upper or lower layers at various sections. These heat flux calculations – or their relationship to the total heat budget – are not described in the Methods section, so it's hard to follow exactly what has been done, but presumably it's a simple calculation of velocity x temperature over the layer. There is one sentence at the end of the Methods sections saying that they "construct the volume and heat budgets within the fjord" following Jackson & Straneo (2016). However, the components of a full budget are not presented, and instead the results are reported in terms of heat fluxes over different layers of a partial cross section. (Also, there is some ambiguity with different control volumes mentioned, but a complete heat budget is not addressed for any control volume, so that's a secondary concern.)

One issue with the results, as reported, is that the heat flux through a transect with a net mass transport doesn't have a clear meaning – it's the heat flux divergence between all bounding surfaces of a control volume that has a well-defined meaning (see, e.g. Montgomery 1974 or Schauer & Beszczynska-Moller, 2009). For example, the text says that, near the glacier, the heat flux in each layer H^f_0 and H^s_0 is smaller with shallower sill, then attributes (without explanation) this to cooler temperatures. But given how these quantities are calculated, couldn't this reduced heat flux be partially or entirely from reduced volume flux? (It's stated that Q_0 also decreases with reduced sill). A comparison of Table 2 and 3 suggestions that heat flux through a layer is largely proportional to the volume flux. This gets at the fact that the heat flux/transport through only one boundary of a control volume does not have meaning in an absolute sense. These calculations of heat transport across partial sections (i.e. over certain layer) will intertwine the temperature of the transport with the volume transport. Relatedly, the heat flux is referred to as the "heat supply to the glacier" – this seems problematic because the heat transport *towards* the glacier in the lower layer largely just feeds into the heat transport away from the glacier in the upper layer. The net heat flux *to* the glacier is a tiny difference between the inflow and outflow.

If heat transports are to be calculated, I would encourage the authors to put these in the context of a total heat budget for the control volume. If you are trying to make heat transport calculations that are relevant to submarine melting, I'd consider defining a control volume between one of the transects and the glacier. Then, the heat flux divergence (i.e. the difference between inflowing and outflowing heat) will go to [1] changing the T of control volume waters, i.e. storage term, and [2] heat for submarine melting. For a control volume that is contained mid-fjord, heat flux divergence should just balance a heat storge term.

When it is claimed that certain cases reach steady state, can you quantify this? E.g. around L296-298, for the "steady" case, it's claimed that the heat exchange compensates for heat loss due to mixing and melting… but did you quantify the heat storage? Is the storage term actually small compared to heat for melting? Here and elsewhere, it would be helpful to define what you mean by reaching steady state.

Also, it would be helpful to be more explicit about what actually sets the melt rate in the model. Heat transport (volume flux x temperature) in the lower layer is not a good metric of heat going to melt. Instead, in this model, submarine melting is calculated from a plume parameterization where melt is going to be a function of 3 basic inputs: the subglacial discharge flux, the near-glacier temperature, and near-glacier stratification N2 (and technically salinity, but let's ignore that for now). First, it would be helpful to say that based on the model setup, the melt will vary with these three parameters. And we know how the modeled melt rate will vary with these three parameters, based on tons of BPT studies. The novel question addressed in this paper is how do sills and reflux modify the near-glacier T and N2. In this model, any change in the circulation regime or heat transport in a layer can't affect the melt rate unless it changes the near-glacier T or N. For example, consider a hypothetical scenario where an increase in subglacial discharge enhances the exchange flow but does not change temperature and stratification near the glacier. Then you would observe an increased magnitude of heat transport in each layer (volume flux*temperature); however, the modeled melt rate would be unchanged, i.e. the net heat going to glacier melt would be the same.

One suggestion – if you don't want this paper to get bogged down in the details of a full heat budget– would be to keep the focus more on the results about how reflux/sills/etc. affects the temperature and stratification near the glacier. These are the two concrete quantities that then go into the melt parameterization to affect the melt rate in a way that we understand. The changes in the Q volume fluxes are also meaningful, as a well-defined quantity to see the impact of sill and reflux. But multiplying together the volume flux and the temperature within a layer gives a quantity of unclear meaning – unless you evaluate the whole heat budget for the control volume. And then, even if you do go this more complicated route, in the end the heat going to melt is determined by the near-glacier temperature and stratification (given the model's melt parameterization), so maybe just focus on reporting those simpler metrics. Related, I would emphasize more that you have an expression to predict the lower layer cooling based on the sill. In the text, this point is somewhat under-emphasized because it jumps right to showing the modeled vs. estimated quantity, which is just a proof that relationship holds, but it doesn't present the main result of how T changes with the controlling parameters (e.g. a plot of T or some metric of cooling vs sill depth).

Around L319, it says that says that reflux "result[s] in less heat supply to the glacier but increased submarine melting". I think this should be "lower heat content near the glacier." Heat supply that actually goes to the glacier *is* exactly proportional to the submarine melting. I think this gets at the point of confusion between heat transport versus changes in heat content (i.e. the heat storage term in a heat budget).

The conclusion implies that regime I and II are steady because heat lost to melting is replaced, whereas regimes III and IV are unsteady because heat lost to melting. Are you confident that regimes III and IV are cooling because of melting? That does not seem supported by the results presented. I would guess that the fjord is cooling because more and more subglacial discharge, which is colder than shelf water, is being mixed into the deep layer. It does not seem to be about heat lost to melting being replaced or not, right?

Finally, two minor questions about the melt implementation in the model: First, is there a heat sink in the way submarine melt is put into the MITgcm? On L44, it says submarine melting is parameterized as a virtual salt flux… is there no heat flux at the terminus associated with submarine melting? Second, at L70-75, the text is a little muddled about submarine melting behind discharge plume versus across rest of the terminus. Are you calculating melt rates across rest of the terminus based on plume velocities (as indicated) or the MITgcm-resolved velocity field or neither? Presumably the melt rates are calculated in the discharge plume using the plume velocity, but what is done for the melt rates across the rest of the terminus?

2) Volume flux calculations in TEF and reflux

First, I found the notation used for the TEF and the reflux formalism a bit confusing. In the paragraph introducing TEF, Q_in and Q_out are defined as landward and seaward transports. But then for the notation on reflux, with Q^in_1, Q^out_1 the "in" and "out" refer to in and out of the reflux control volume, not landward or seaward. Also, in this latter case, you can't know whether in/out is landward/seaward or upper/lower layer without knowing where the sections are relative to the control volume. I found this all a bit confusing, especially given the common practice of having "in" and "out" refer to landward and seaward in an estuary. Also, is there a reason to define yet set of layer notation with U_upper and U_lower, etc on L217? (More minor, but it's also slightly confusing how sometimes the 1/2/3 section indices are subscripts and sometimes superscripts.)

Second, it seems like the beauty of the reflux calculation is that it "expresses vertical fluxes as volume transports, which is equivalent to the horizontal fluxes in TEF". But then I'm slightly confused about the fact that the layers seemed to be defined differently in TEF vs. the reflux calculations. For TEF, the layers are determined with the 'dividing salinity' method, whereas for reflux calculation the layer interface is determined by zero-crossing in the velocity profile. Is this consistent? Can you explain?

Also it's a little unclear to me how the material in the Results section around L228-233 about calculating TEF transports relates to the methods outlined in the Methods section. Is this just repetitive or is something different being said? Should it be here or in Methods?

For both the TEF and reflux calculation, it seems that a 2-layer system is assumed, but how do these calculations work with the regimes that have a 3 layer circulation pattern?

In Table 3, the difference in upper and lower layer volume flux is exactly 250 m3/s, the subglacial discharge input, for all columns. This is required by mass conservation, right? Thus maybe you only need to show the volume flux in one layer (can state in caption or text that the other layer is the same flux, plus or minus the FW input). Also, you could consider making this into a plot of volume flux vs. h_s/h_f – might be easier to see the trends.

Finally, I found it somewhat confusing how there's a discussion in the text of Table 3, about how the sill affects volume flux in terms of Q_0^s and Q_0_f. And then later, there's another discussion about how the sill affects the volume fluxes of Q^2_in and Q^1_out. Could these be consolidated?

3) Testing the scaling for terminal depth of plume

In this section where you test the scaling for the terminal depth of the plume, is this just testing the plume parameterization at the glacier boundary of the MITgcm domain? My understanding is that the scaling from Slater et al (2016) is derived from BPT, and then here you're testing if it works well for the MITgcm plume module, which employs BPT to represent the plume. This seems a bit circular, unless I'm missing something. I understand why it's helpful to introduce the scaling, but it seems like could just be a sentence that says, "based on a BPT study, terminal height of plume scales with (N^2)^(-3/8), and our simulations follow this scaling since the plume module uses BPT to calculate the depth of injection into the fjord domain…" or something. The interesting point is that the sill/reflux changes N^2, and so that changes the terminal height of the plume, right?

In any event, I would try to make clear if this part is testing anything about what is modeled within the MITgcm domain, or is this just testing the BPT parameterization of the plume, in which case there doesn't seem to be anything novel in testing a scaling that was derived from BPT.

Minor comments

a) How many grid points in the vertical direction are over the sill? For the shallower sills, is this sufficient to resolve sill-related mixing and reflux dynamics?
b) Abstract and L250: I don't think a % is the best way to quantify cooling. 10% cooling with degrees Celsius would be a very different % on Fahrenheit or Kelvin temperature scale. Would just drop the percentage and say in degrees, or I guess it could be a percentage reduction in the temperature above freezing.
c) When discussing the result that most of the vertical transport occurs over the sill (L206), isn't that is somewhat by design since there is no topography anywhere else in the fjord? Realistic bathymetry with bends and shallow sides would promote some enhanced mixing. In this case, the sill is really the only place that the flow interacts with

topography since it's a rectangular fjord. This seems like a relevant caveat to mention when stating this result.

d) In Regime III, when the outflow hits the sill and feeds into the deep layer which is then drawn back towards the glacier, why is this not reflux? Seems like the outflowing layer feeds the deep inflow layer, right? L323 states that "reflux barely generated when plume-driven outflow progressive fills…" – but why isn't it reflux?

e) I found the section on tides a bit confusing. One place is says melt increases by 6-30% with tides, then a few sentences later says melt "stayed unchanged with higher tidal amplitudes". Also, I don't quite follow the explanation of why reflux decreases with introduction of tides – could you try explain this a bit more clearly?

Line by Line

L19: citation for first half of sentence?

L25, missing comma: "freshwater, leaving"

L32: typo? "no deep or no sill"

L47: "besides" – word choice

L94 shouldn't "h_s" be "h_f"?

L95: what do you mean the "fjord domain is set to 2 km"? what dimension is that? The previous sentence says the width is 4 km, and the length seems to be 20 km in Fig 1.

L96: typo, "this *does* not prevent"

L97: says h_f is 400 m in all simulations, but doesn't Table 1 say that h_f is 200 m in one set? Or what is h (second column) in Table 1?

L110: missing units on Coriolis parameter

L113: here and elsewhere, the "~" symbol should be replaced with a dash

Table 1: shouldn't "h" be "h_f"?

L135: missing word: of "of *whether* they are…"

L179 typo "with with"

Figure 3: label glacier location on these (optional, just a suggestion)

L 181: "As the sill depth increases" → ambiguous wording, would say as the sill becomes shallower.

Table 2 & Table 3: specify for which set of experiments? Looks like this is the first set from Table 1 where Qsg is held constant at 250 m3/s, right?

Figure 6: put a box around the upper left corner point – I assume this is a legend, but it looks like a data point

L241. Cite Figure 5 here?

L249" cite Figure in this sentence about cooling?

L256-258: reword this sentence and how it related to the one before

L275: typo? how can hp/hf be greater than 1? Wouldn't hp/hf = 1 be the plume at surface, and hp/hf<1 be subsurface plume… so hp/hf>1 would be plume above the surface?

Figure 11: the U and T profiles sketched on panel c does not match up with the arrows… should the blue outflow arrow be roughly the same height as the peak of positive U velocity and negative T?

L326-326: run-on sentence

Increasing number of typos towards end of the paper.

L386: should this be H_f^0 or H_s_0? Also, this doesn't make sense to me

L398: "where background melting dominates the freshwater output"… Background melt is shown to be a significant portion of the total submarine melt, but not the total freshwater input (subglacial discharge is still much larger)

Label/refer to regimes in text, if going to label them in figures