**Review of Impact of Shallow Sills by Bao and Moffat**

Based on ocean-circulation modelling, this paper examines circulation in proglacial fjords where the exchange flow is primarily driven by buoyancy forcing from subsurface ice melt and subglacial discharge. More than seventy numerical experiments have been conducted to investigate how the fjord circulation depends on conditions such as sill height, ambient water temperature and stratification, and tidal flow. The paper offers many interesting results, including how high sills can cause a transition to hydraulically-controlled exchange flow, which induces cooling and recirculation in the waters between the sill and the glacier. However, some of the main findings could be presented in a more general and accessible way; particularly making limitations of the results clearer when applying them across seasons and between oceanographically different fjord systems.

# Main comments

## How is the model stratification set?

It is not clearly described how the stratification is set in the model in section 2.1. Are the authors restoring to the idealised Greenlandic profile in the open-ocean part of the model domain? Or are they initialising the model with a stratification that is allowed to evolve in the simulations? This issue is highly important for the interpretation of the model results; it decides if the simulations yield fjord stratifications that are determined by the interplay between melt dynamics, the sill, and the open ocean conditions. (The results in Fig. 7, for example, make me suspect that the stratification is set by the initial conditions.) Explain this clearly.

## The sill height

The authors use the ratio between the sill depth ($h_s$) and the fjord depth ($h_f$) as a measure to distinguish/discuss flow regimes, and also refer to effects of hydraulically-controlled exchange flows. However, in a two-layer description of hydraulic flows (see e.g. Pratt and Whitehead, 2007) it is only the upstream height of the layer interface above the sill crest that matters for the dynamics — the fjord depth does not enter. The authors need to expand on this matter and discuss how the specific $T$ and $S$ profile they use as initial conditions (or restoring open ocean conditions?) relates to the impact of $h_s$ on the flow. [L102: here you should describe the idealised Greenlandic salt stratification and estimate an approximate two-layer representation of the vertical density distribution; with an interface depth of say $h_i$: Note that $h_s - h_i$ and the layer density difference are key variables determining the flow characteristics (see e.g. Pratt and Whitehead, 2007; Schaffer et al., 2020; Nilsson et al., 2022).]

Results of for instance Jakobsson et al. (2020), Schaffer et al. (2020), and Nilsson et al. (2022) show that hydraulic control can emerge in North Greenlandic fjords with marine glaciers that have relatively deep sills ($h_s \approx 400$ m) where $h_s/h_f \approx 0.5$. It could be relevant to mention that the present study to some extent also reveals impacts of sill geometry on the exchange circulation and reflux in such fjord systems.

### Submarine melting

If the flow is hydraulically controlled, a taller sill is expected to diminish the ocean heat transport towards the glacier, and hence to reduce the subsurface melt (Schaffer et al., 2020; Nilsson et al., 2022). A puzzling result of Table 3 is that the shallowest sill experiment yields slightly higher subsurface melt that the "no sill experiments", with the highest melt found for $h_s/h_f = 0.12$. Can you explain this? (Are the experiment transient in character and do not give equilibrated melt rates?)

Additionally, could some general information in Tables 2 and 3 be extracted and represented graphically in a figure? I find it difficult to digest the results in the tables.

### Unsteady flow regimes

The authors present four flow regimes, two of which are unsteady. In regime III, freshening due to subsurface melt will continuously increase the buoyancy of the fjord water below the sill level. Also in regime IV, the subsurface melt increases the buoyancy of the fjord water, and at the same time the exchanges flow transports buoyancy into the fjord. In both cases, the fjord will convectively overturn after sometime, establishing a circulation in the regime I or II. The question is after how long.

On L345, the authors state that their results suggests that Regime IV may persists on seasonal timescales. There seems to be very little support for this statement. Furthermore, the lifespan of transient regimes like III or IV can presumably vary greatly, depending on the particular fjord system and what processes that forced a transition into the transient regime. This needs to be discussed and better quantified.

### Language

Please improve the language: there are grammatical mistakes and some formulations that are a bit unclear.

## Minor comments

L1: perhaps change "of glaciers is" to "of ice sheets are" (since glaciers are not main contributors to sea level).

L8: "leads to 10% cooling". Obviously, the cooling rate depends on reflux as well as the temperature difference between inflowing and outflowing waters. Thus, "leads to 10% cooling" needs to be related to actual temperatures or a specific fjord type; e.g. an Alaskan fjord in summer.

L103: Are you restoring to the idealised Greenlandic profile in the open-ocean part of the model domain? Please explain.

L119 and Table 1: The authors are analysing many cases, and it may be helpful if they define a reference case, meant to characterise a particular fjord (or group of fjords). The authors use a Greenlandic salt profile, and mention glaciers in Patagonia and Alaska. I note that in most of the experiments, the temperature is 10 °C. This is much warmer than subsurface Atlantic Water temperatures around Greenland (Straneo et al., 2012). So to present one reference case would be helpful.

L123: Is subglacial discharge values used here small or large for a 2 km wide fjord? I would expect that a subglacial discharge of 1000 m $s^{-1}$ into a 2 km wide fjord is a bit extreme; or even unrealistic?

L174: "driven only by subglacial discharge"; I suppose you mean driven by the temperature forcing and subglacial discharge.

Fig. 3: mention the temperature of the experiment.

Table 3: I assume that "$h_s/h$" should be "$h_s/h_f$". Also, why do not $Q_0^f$ and $Q_0^s$ balance each other? Is this due to the plume parametrisation?

Figure 7 and Eq. (6): I repeat that I don't understand how the salinity stratification is set or prescribed in the model (see main comment and L103 above). If the stratification would have been restored in the open ocean, then I don't see how this could affect the stratification below the sill level in the fjord. Explain what is going on.

L420: "With a sill depth of $h_s/h_f = 0.04$, about 70% of the plume-driven outflow is refluxed to depth." As stated in the major point, $h_s/h_f$ is essentially irrelevant for whether the flow is hydraulically controlled, and outflowing glacially-modified water is entrain into the inflowing oceanic water.

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