# Seasonal variability of submarine melt rate and circulation in an East Greenland fjord

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## Abstract

The circulation in Sermilik Fjord is investigated using a non-hydrostatic ocean general circulation model with a melt rate parameterization at the vertical glacier front. The two-layer stratification of the fjord's ambient waters causes the meltwater plume at the glacier front to drive a 'double cell' circulation. In summer, the discharge of surface runoff at the base of Helheim Glacier causes the circulation to be much more vigorous and associated with a larger melt rate than in winter. Seasonal differences are also present in the vertical structure of the melt rate. The simulated 'double cell' circulation is consistent, in both seasons, with observations. Simulated submarine melt rates are strongly sensitive to the amount of subglacial discharge, to changes in water temperature, and to the height of the layers.

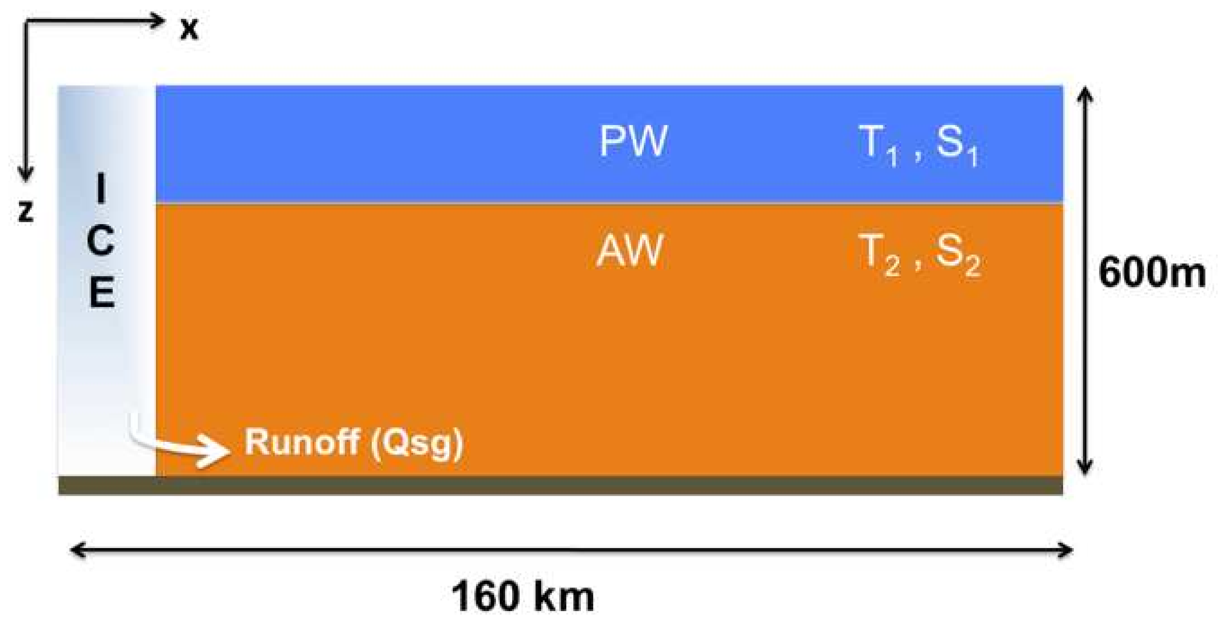
## 1. Question addressed

## Seasonal and oceanic variability influences fjord circulation and submarine melting?

## 2. Model Formulation

**To explore the seasonal variability we consider a glacier/buoyancy driven circulation without external forcing and with a variable runoff distribution. To explore the oceanic variability we consider changes in the AW properties inside the fjord.**

2D, non-hydrostatic, high-resolution configuration of the MITgcm with a geometry ideally based on the topography of Sermilik Fjord.

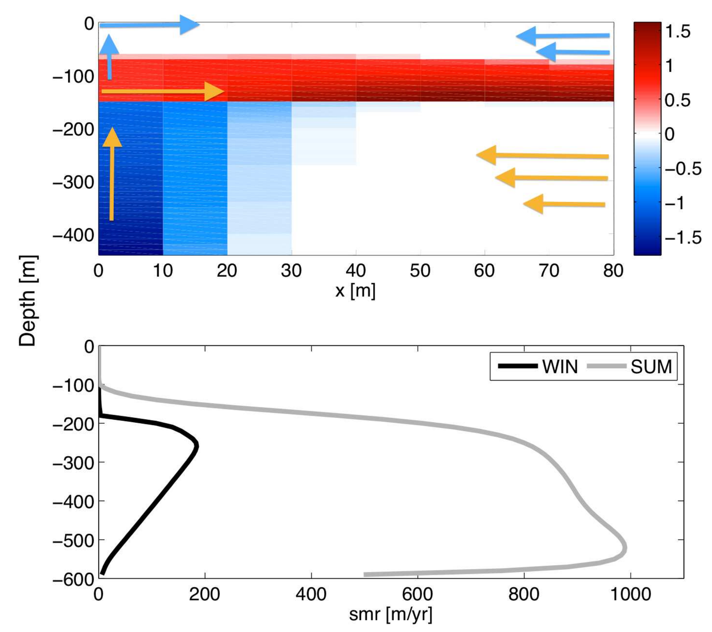



Model geometry with 10*m* horizontal and vertical resolution. $T_1 < T_2$, $S_1 < S_2$

Profiles collected Sermilik Fjord are used as initial and boundary conditions for temperature and salinity. The mostly along-fjord water property changes allow for a 2D setup.
The ice-shelf thermodynamics is based on the three equations model with velocity dependent turbulent transfer coefficients

$$T_b = \lambda_1 S_b + \lambda_2 + \lambda_3 P_b$$
$$c_p \rho C_d^{1/2} \Gamma_T (T_w - T_b) = -L_i q - \rho_i c_{p,i} k (T_i - T_b)$$
$$\rho C_d^{1/2} \Gamma_S (S_w - S_b) = -S_b q$$

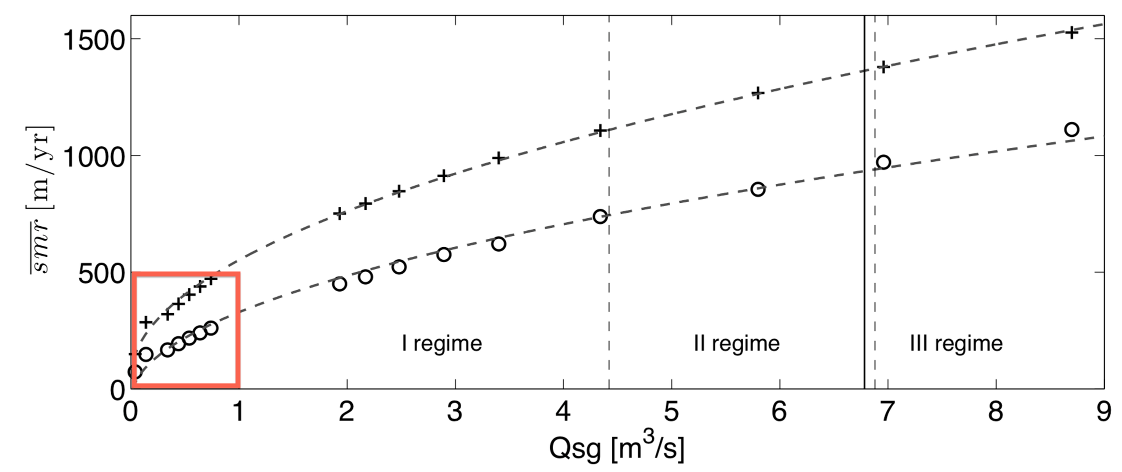
## 3. Model results - Seasonal variability




(top) Schematic of summer fjord circulation overlaid on the salinity anomaly, (bottom) winter and summer vertical profiles of submarine melt rate.

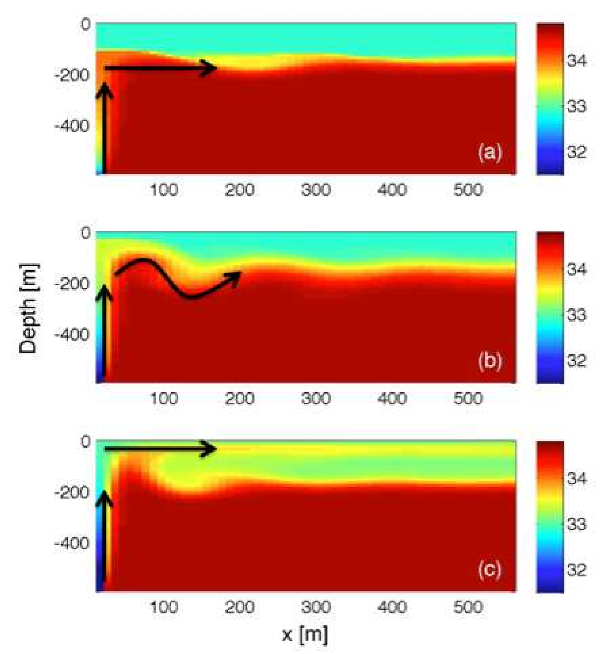
Due to the two-layer stratification, a 'double cell' circulation is found year-round.
Large seasonal variability of $\overline{smr}$ driven by runoff.
The vertically averaged $\overline{smr}$ changes of one order of magnitude from winter **(70 m yr$^{-1}$)** to summer **(738 m yr$^{-1}$)**.
The *smr* is maximum at the **AW/PW interface** in winter, and at the **bottom of the glacier** in summer.

The velocity dependent $\gamma_{T,S}$ are crucial to represent the $\overline{smr}$ vertical profiles and magnitude.




The submarine melting has a sublinear, with the power 1/2, dependence on subglacial discharge both in its averaged (circles) and maximum (crosses) values

## 4. Model results - Dynamical regimes




Salinity distribution near the glacier front. Regime I (top) = $\rho_l > \rho_1$, Regime II (center) = $\rho_l \sim \rho_1$ Regime III (bottom) = $\rho_l < \rho_1$

As the subglacial discharge increases, the dynamics evolves into three different regimes.
The transition between these regimes can be estimated by comparing the density of the PW layer ($\rho_1$) with the density of the plume at the interface ($\rho_l$)

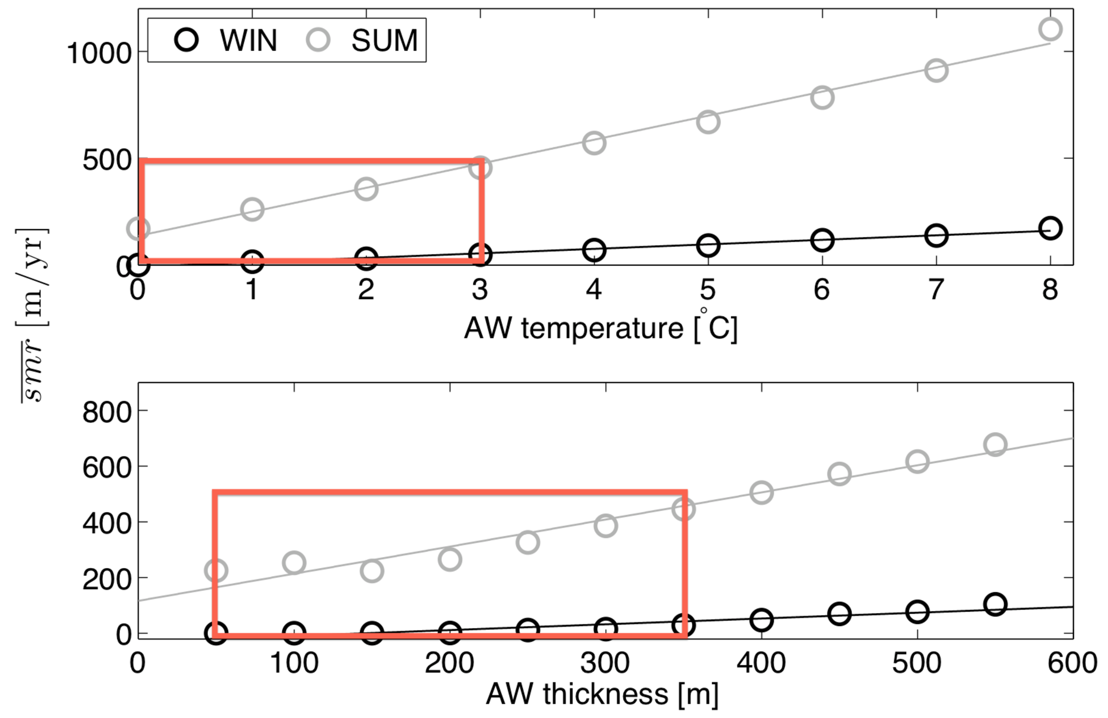
$$\rho_p(z) = \frac{\rho_{p0} Qsg + \rho_a Q_e(z)}{Qsg + Q_e(z)}$$

where $Q_e$ is the flow of entrained ambient waters

$$Q_e(z) = \alpha w A_p(z)$$

## 5. Model result - Oceanic Variability

The $\overline{smr}$ is only sensitive to AW properties and, runoff is one of the main driver of the dynamics.
$\overline{smr}$ depends linearly on AW temperature and thickness and has a small dependence on AW salinity.



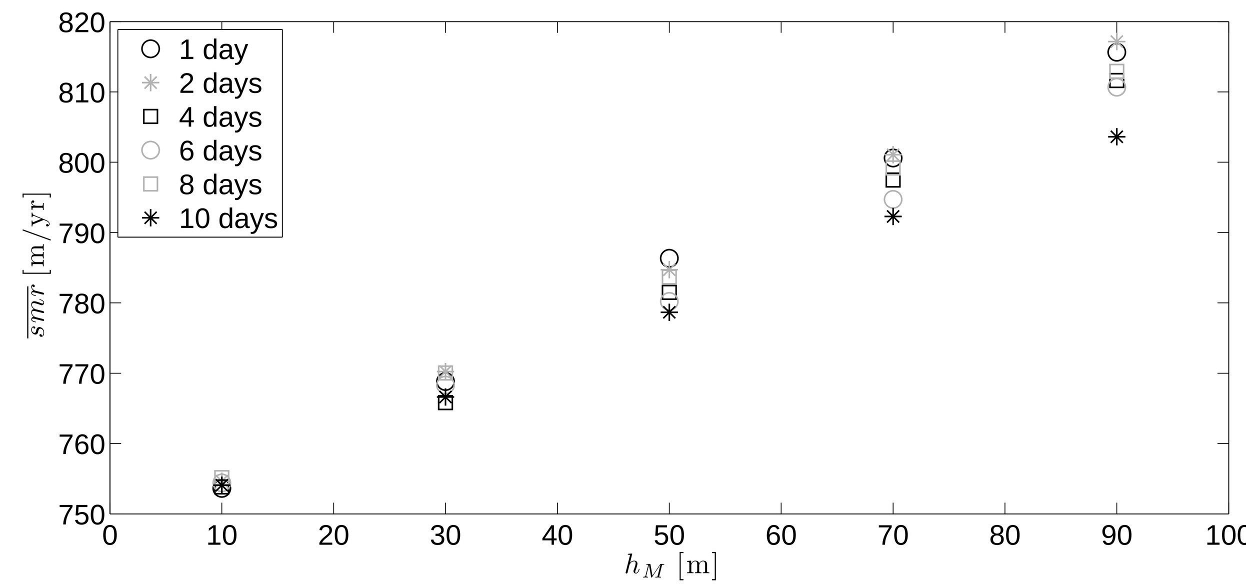

Vertically averaged submarine melt rate as a function of AW temperature and thickness.

Increasing the AW temperature form 4° to 5° is comparable to increasing the AW thickness from 450m to 500m. The layer's thickness may be as, if not more, important than a temperature change in the AW layer.

## What's next?

### Can externally/oceanic driven circulations change this dynamics?


Model geometry and schematic of the periodic boundary conditions at the fjord's mouth with the layer's interface moved upward and downward




## Reference

[1] R. Sciascia, F. Straneo, C. Cenedese, and P. Heimbach. Seasonal variability of submarine melt rate and circulation in an east greenland fjord. *Journal of Geophysical Research: Oceans*, 118, 2013.

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