Glacier–plume or glacier–fjord circulation models? A model intercomparison for Hansbreen-Hansbukta System, Svalbard

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1. Background & aims

Model estimations of Sea Level Rise to the end of century are between 79 – 157 mm [Huss & Hock, 2015], and point that **Tidewater Arctic glaciers** might be the **largest contributors** [Marzeion et al., 2017]

3 main mechanisms of mass loss
(interrelated)

- **Surface Melting** → percolation + melting at bedrock→ subglacial discharge [e.g. Chu 2014; Beaird et al. 2015]
- ↓
- **Submarine Melting** [e.g. Motyka 2013; Straneo & Heimbach 2013; Cowton et al. 2019]
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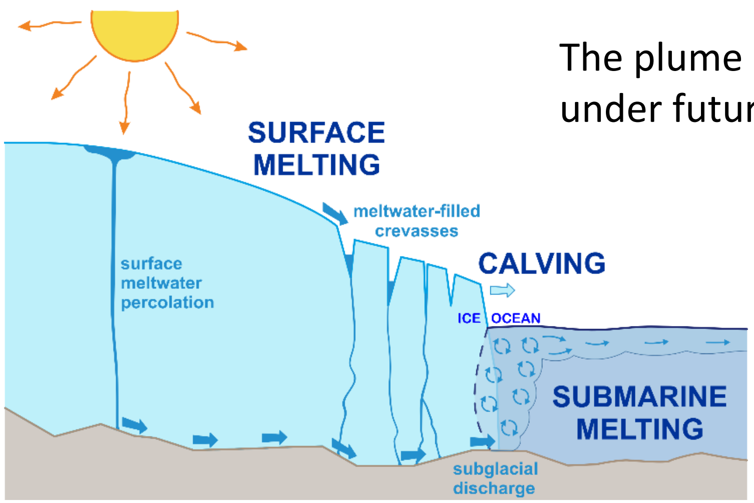
- **Calving** [e.g. Benn et al. 2007; Nick et al. 2010; How et al. 2019]

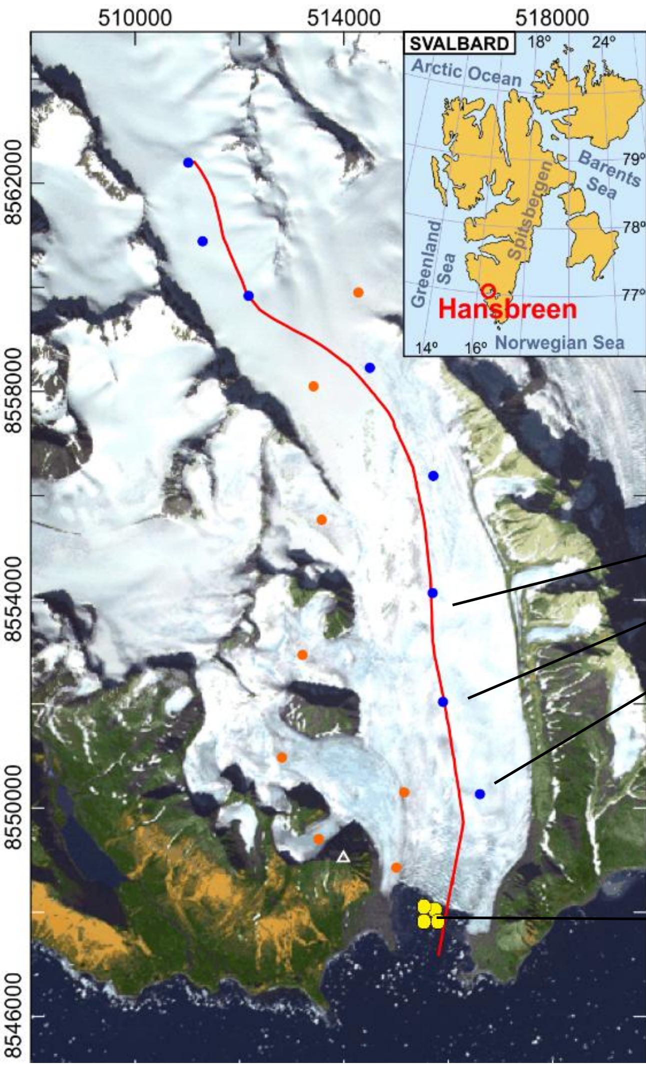


The plume model is widely used to estimate submarine melting under future scenarios, but … [e.g. Beckman et al. 2019; Slater et al. 2019]

- **How different are submarine melt rates resulted from fjord-circulation or plume models?**
- **How this might affect modeled calving rates and/or front position changes?**

2. Hansbreen-Hansbukta system & data

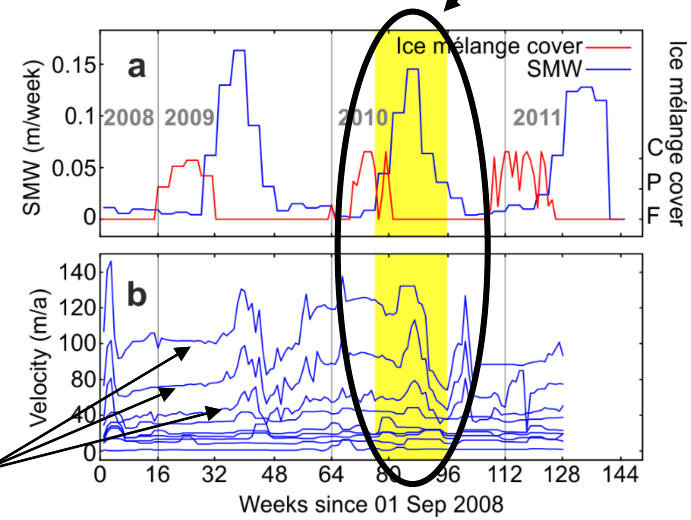
Glacier and fjord data overlap (Apr-Aug 2010)



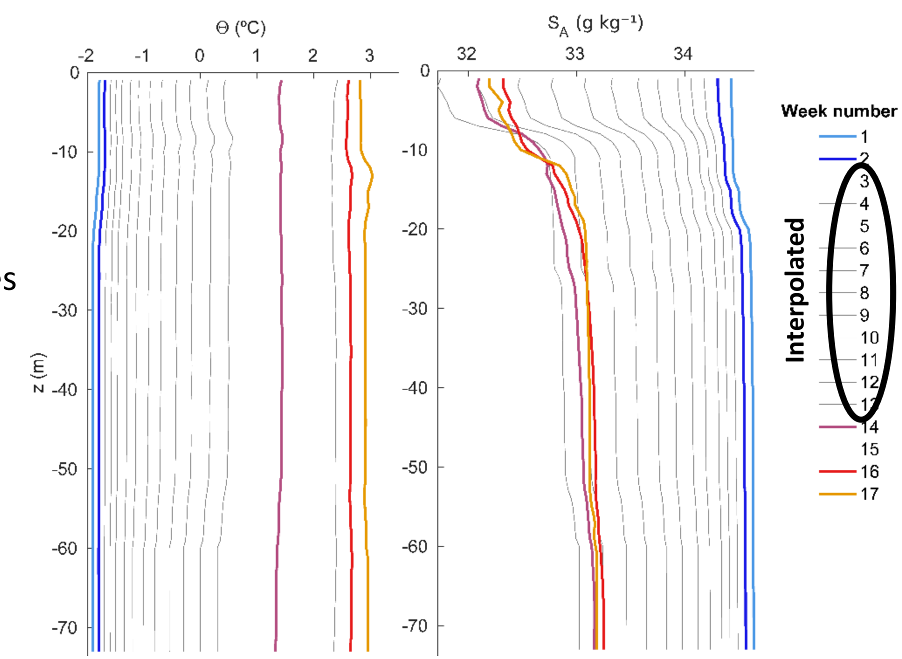
Hansbreen, around 16 km long, 1.5 km wide and 100 m thick at the front (50-60 m submerged). Hansbukta, 2 km long, 1.5 km wide, 90-20 m deep.

Surface meltwater & ice mélange

Ice velocity (stakes)

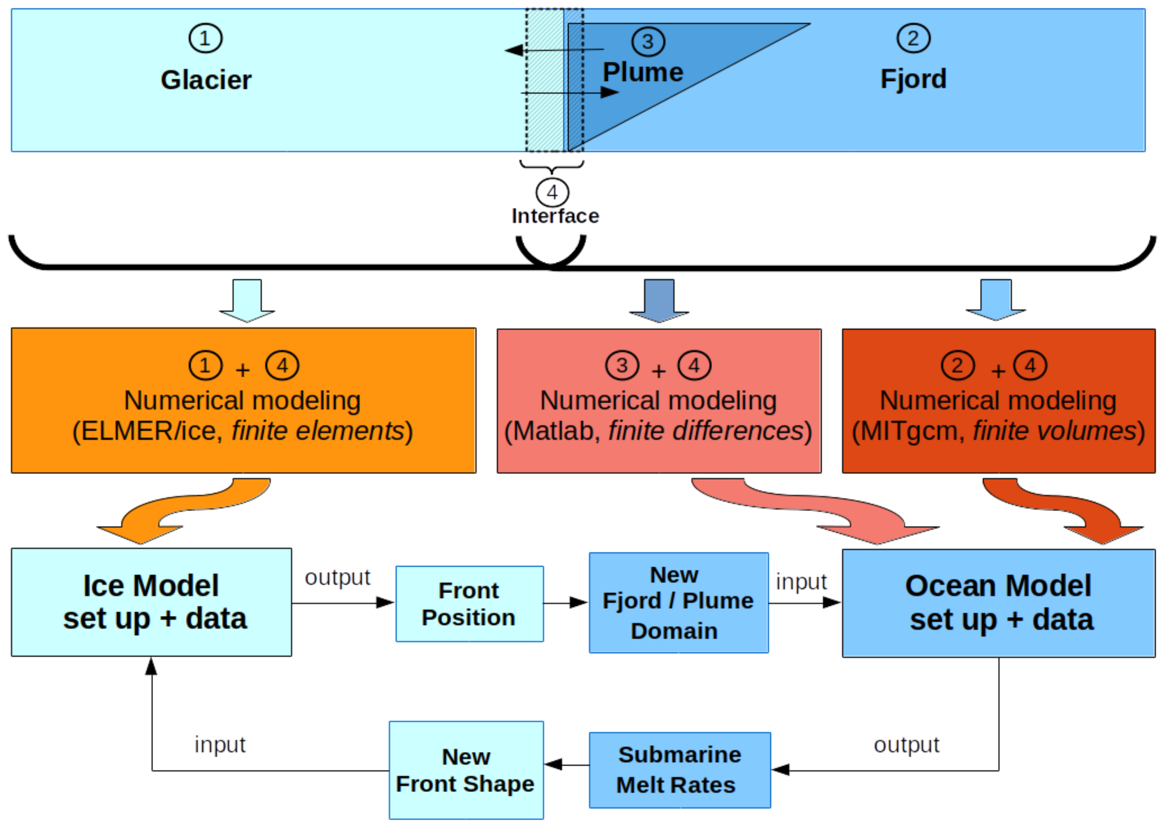


Fjord temperature and salinity profiles (CTDs)

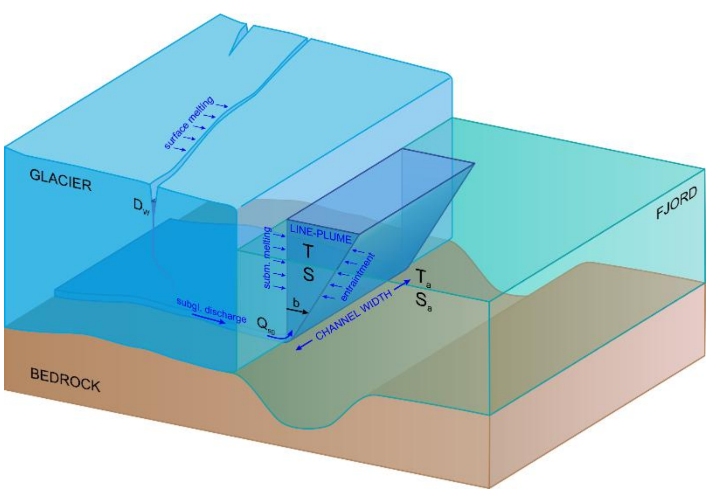


3. Methods

1. Coupling of **Glacier-Plume** and **Glacier-Fjord** models through **submarine melting** at the ice-ocean interface and **front position** changes.



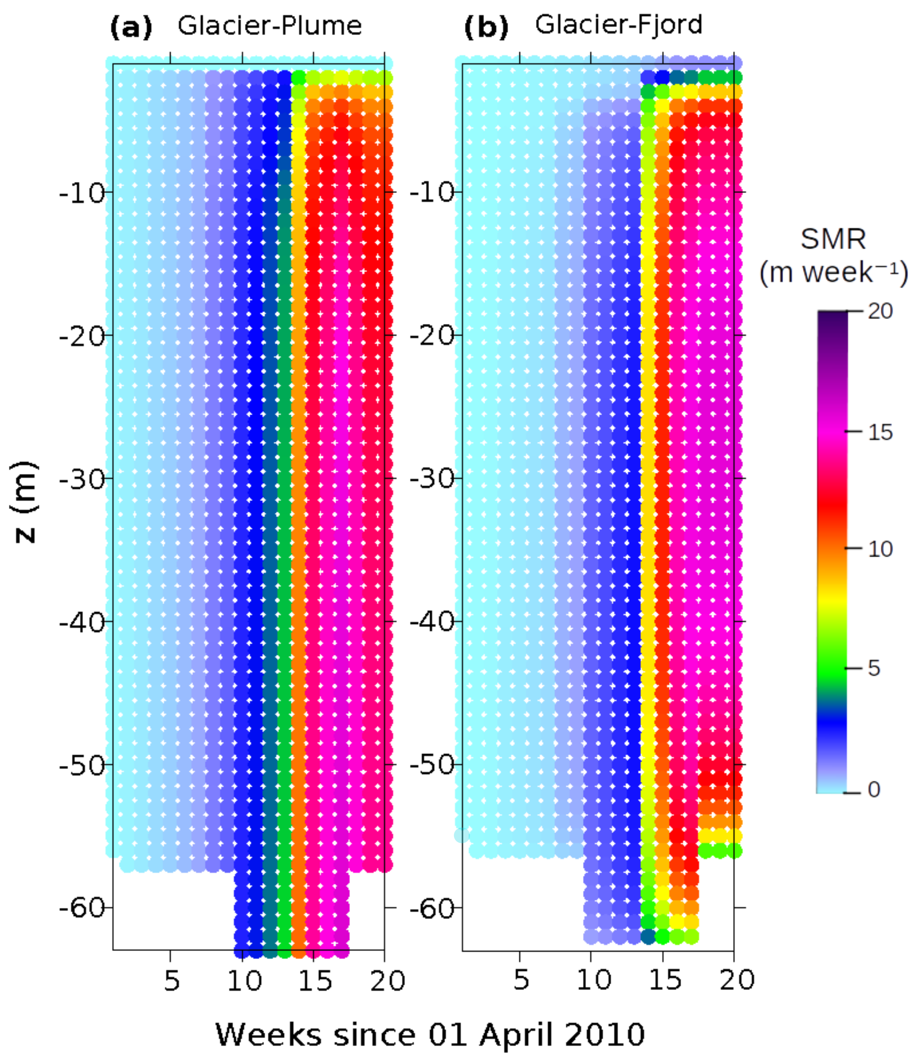
2. Simulation of Hansbreen-Hansbukta system during Apr-Aug 2010 (20 weeks) using the **same configuration in both coupled models** (transient data for boundary conditions, subglacial discharge fluxes, ice velocities, etc)



3. Comparison between glacier-plume and glacier-fjord results:

i. Submarine melt rates
ii. Submarine front shapes from melting
iii. Glacier net stress
iv. Glacier front position

4. Results: (i) Submarine melt rates



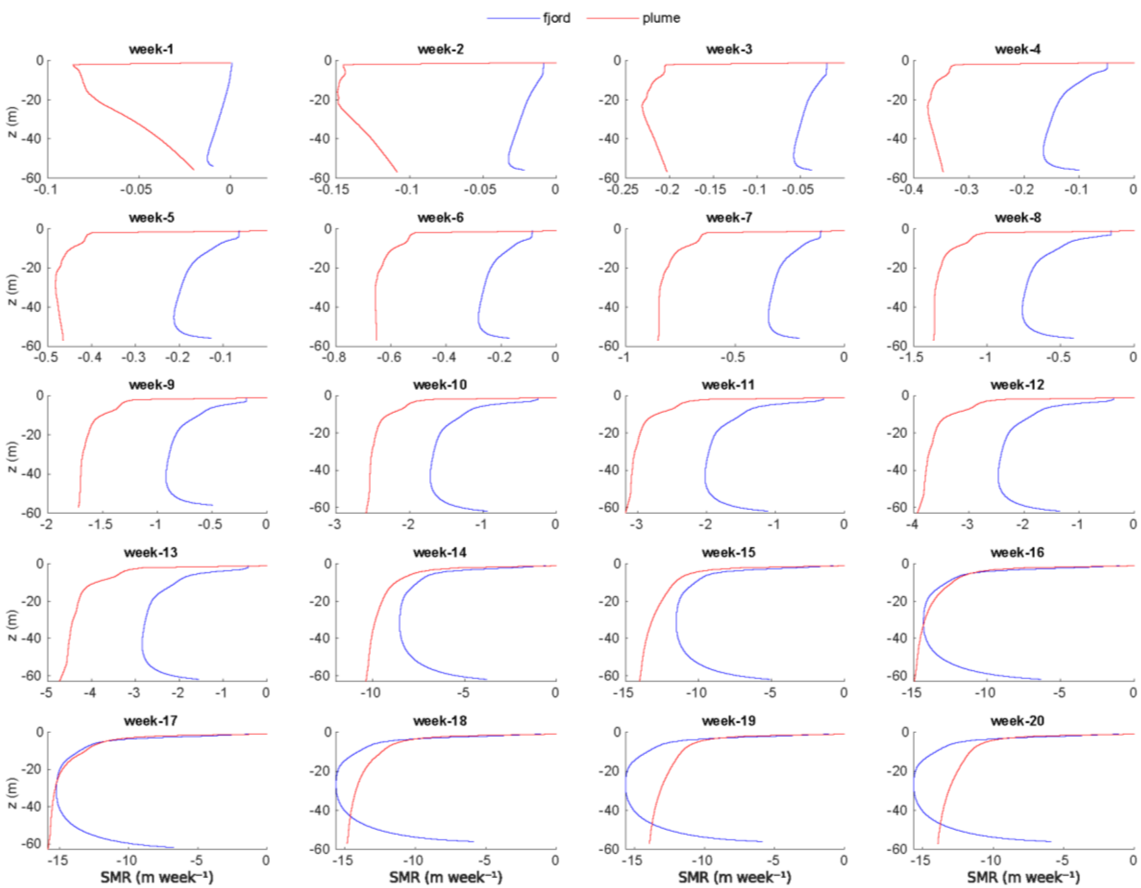
- In both models, submarine melt rates showed high sensitivity to the intraseasonal evolution of subglacial discharge and fjord temperature.
- Max. depth-dependent melt rates of the glacier-plume (-fjord) model ranged from 0.1 (0.01) m week^{-1} in April up to 16 (16) m week^{-1} in August.
- These maxima occur at depth in the glacier-plume model and at mid-depth in the glacier-fjord model (different profiles of submarine melting).

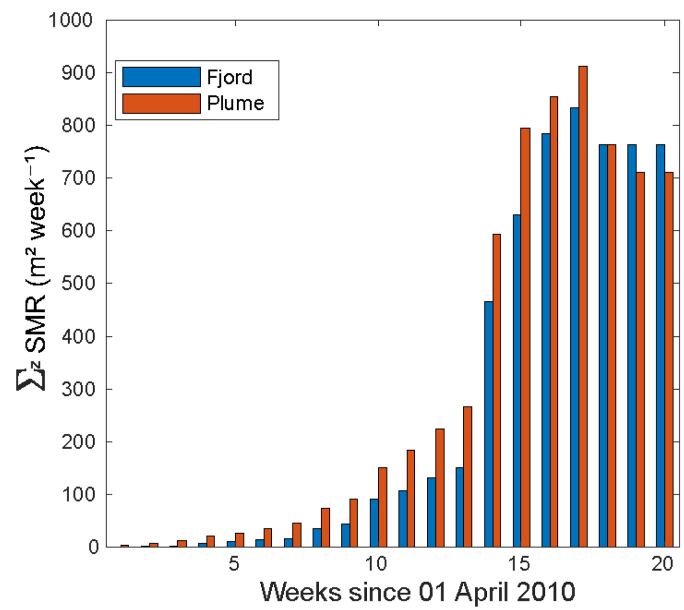
4. Results: (ii) Submarine front shapes from melting

- Glacier-plume and glacier-fjord coupled models show different melt-undercutting front shapes.

- Glacier-plume model showed a quasi-linear melt-undercutting morphology, whilst a quasi-parabolic front shape resulted from the glacier-fjord model. [see Beaird et al. 2019 and Sutherland et al. 2019]

- Both models differ in vertically-accumulated submarine melt rates (up to 30 % higher for the glacier-plume model).



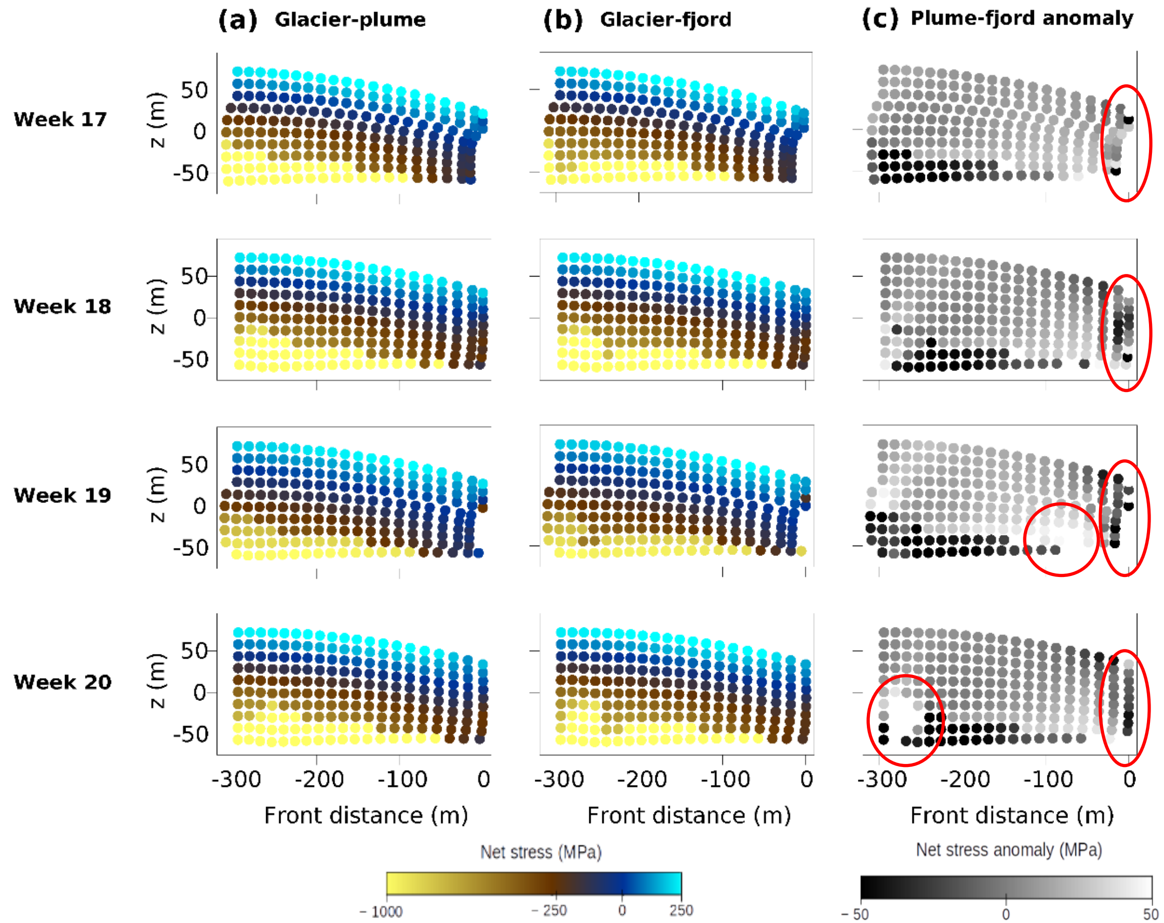


4. Results: Glacier (iii) net stress and (iv) front position

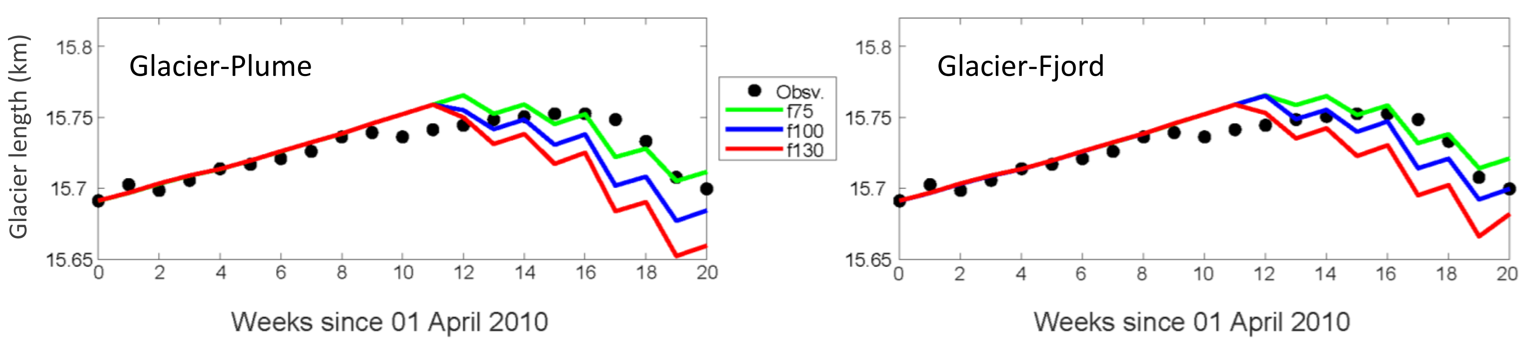
- Net stress anomalies near the glacier front were detected between the two models at the end of the summer (higher subm. melt rates).

[see Ma & Basis 2019]

- The glacier-plume model showed higher calving rates.



- Despite all, both models predicted similar front positions.



5. Conclusions

- **Glacier-plume and glacier-fjord coupled models** differ in vertically-accumulated submarine melt rates (up to 30 % higher for the glacier-plume model) and **show different melt-undercutting front shapes**, which have an influence on the net stress fields near the glacier front.

- The quasi-linear melt-undercutting morphology exhibited by the glacier-plume model promotes higher calving rates than the quasi-parabolic front shape resulting from the glacier-fjord model, although **both models predict similar front positions** under best-fit scenarios.

- The computational cost of the glacier-plume model is 0.02 times that of the glacier-fjord model → **Glacier-plume model, good tool for projection studies** (**if appropriate constraints of subglacial discharge fluxes and ambient fjord temperatures are applied**).

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