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 \(\rightarrow\) percolation + melting at bedrock\(\rightarrow\) subglacial discharge

  [e.g. Shcneider 1999; Chu 2014; Beaird et al. 2015]

Submarine Melting

  [e.g. Motyka 2011, 2013; Straneo et al. 2012, 2013; Cowton et al. 2019]

Calving

  [e.g. Van Der Veen 1996; Benn et al. 2007; Nick et al. 2010]

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

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.

Interpolated Glacier and fjord data overlap (Apr-Aug 2010)

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.

- 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).

• 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.

• 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 (as long as we apply appropriate constraints to subglacial discharge fluxes and ambient fjord temperatures).

Thank you for looking at our display!