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Are the flow dynamics of Jakobshavn Isbræ driven by calving?

Calving rate observations and modelling, 2009 to 2017

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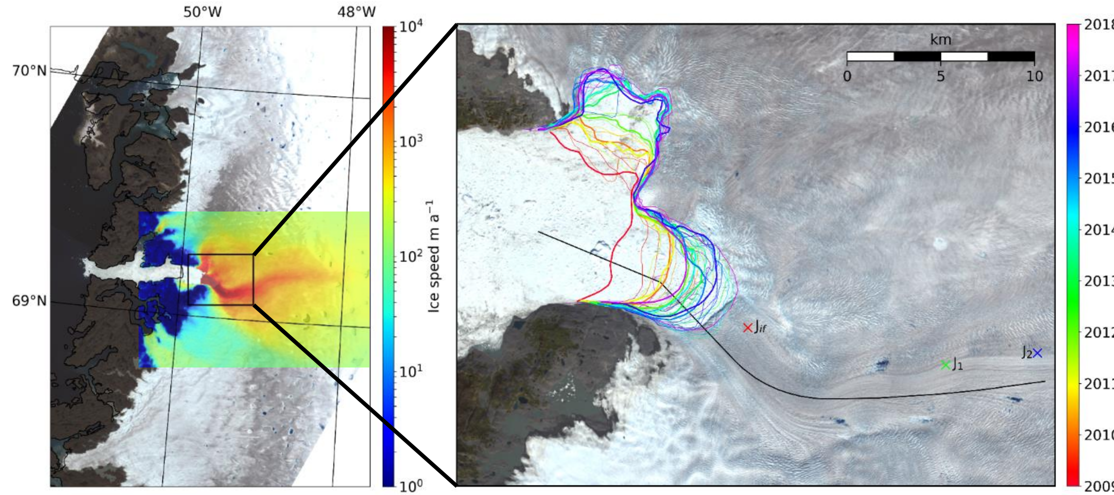
1. Background

- Jakobshavn Isbrae has rapidly accelerated and retreated since the late 1990s, entering a phase of stability from ~2004 onwards.
- Further retreat from 2009, with maximum speeds attained in 2012 and 2013.
- Modest deceleration, readvance and thickening since 2016.



Velocity structure and smoothed quarterly calving fronts for Jakobshavn Isbræ. Background images from Landsat 8, August 9th 2016. Velocity from [1] (version 4). Calving fronts from [2], [3]. Thicker calving front denotes winter position.

Ice velocity of Jakobshavn Isbræ, Petermann Glacier, Nioghalvfjerdsfjorden, and Zachariæ Isstrøm, 2015–2017, from Sentinel 1-a/b SAR imagery

Adriano Lemos[1], Andrew Shepherd[1], Malcolm McMillan[1], Anna E. Hogg[1], Emma Hatton[1], and Ian Joughin[2]

Interruption of two decades of Jakobshavn Isbrae acceleration and thinning as regional ocean cools

Ala Khazendar[1*], Ian G. Fenty[1], Dustin Carroll[1], Alex Gardner[1], Craig M. Lee[2], Ichiro Fukumori[1], Ou Wang[1], Hong Zhang[1], Hélène Seroussi[1], Delwyn Moller[3], Brice P. Y. Noël[4], Michiel R. van den Broeke[4], Steven Dinardo[1] and Josh Willis[1]

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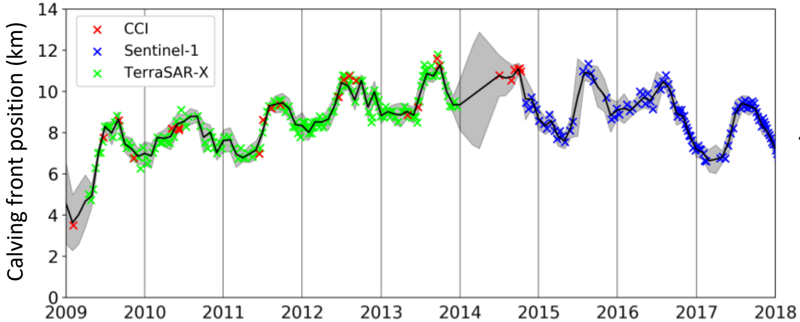
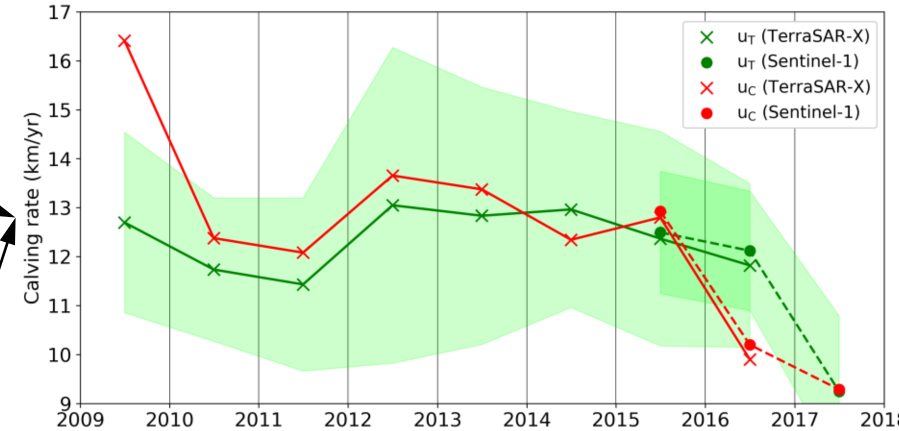
2. Calving rate, 2009 to 2017

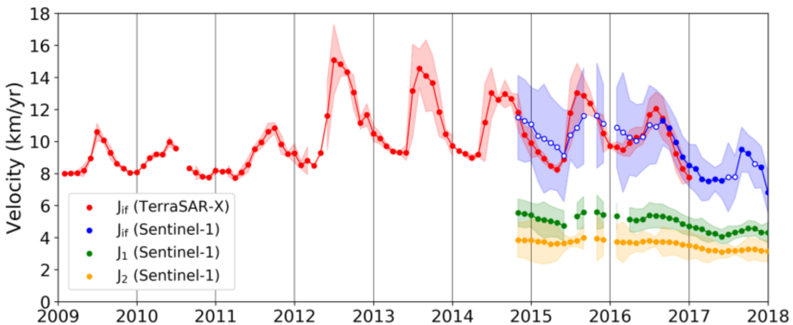


Timeseries of calving front position along flowline. Calving fronts from [2], [3]



Mean annual calving rate (red) and terminus velocity (green)

$$u_C = u_T - \partial L / \partial t$$



Timeseries of ice velocity, data from [4],[5], extends previous timeseries

- Error bars on calculated mean annual calving rate are very wide! (not shown)
- Correlation between u_C and u_T for most years. Delayed deceleration from 2016 to 2017 following reduction in calving rate. Suggests influence of rate of calving on flow dynamics.
- Can we drive ice flow evolution by an applied calving rate?

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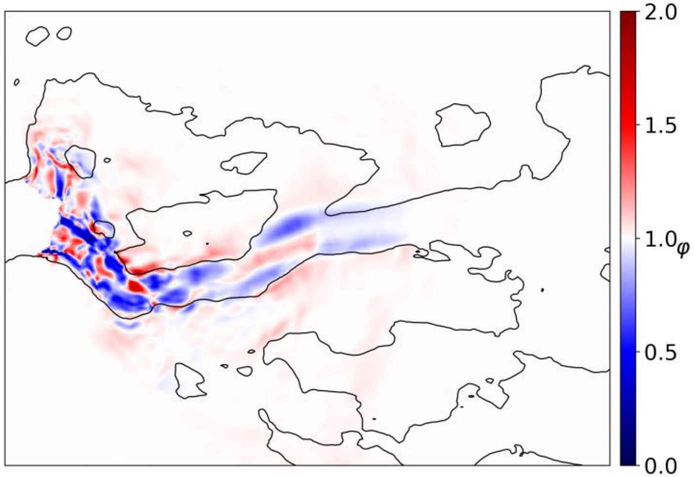
3. Transient ice sheet model initialisation in BISICLES [6]

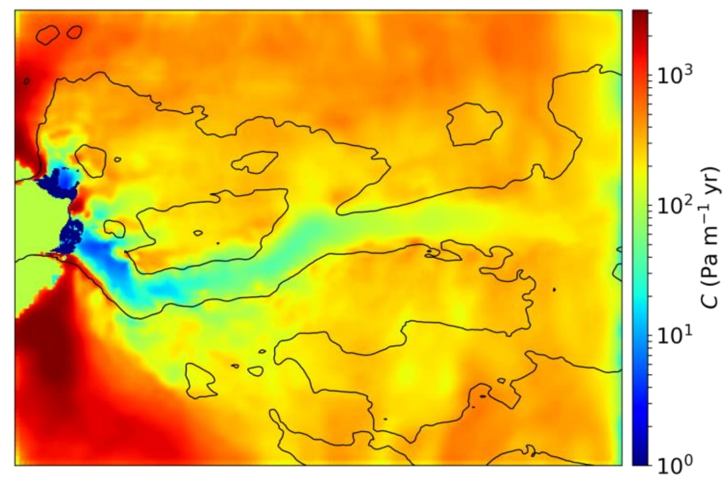
- Optimise fields for basal traction coefficient (C) and stiffening factor (φ) for by minimising an objective function[7]:

$$J = \int_{\Omega} \alpha_u^2(x,y)(|\boldsymbol{u}| - |\boldsymbol{u}_o|)^2 \, \mathrm{d}\Omega + \alpha_C \int_{\Omega} |\nabla C|^2 \, \mathrm{d}\Omega + \alpha_\varphi \int_{\Omega} |\nabla \varphi|^2 \, \mathrm{d}\Omega$$

- C and φ input fields produced for individual quarterly periods from 2009 to 2017, by applying additional transient regularisation to suppress high frequency temporal variation.
- The resulting fields will be used as inputs for the forward modelling run.



Inverted ice stiffening factor, Q1 2009. Vertically-integrated effective viscosity: $\varphi h \bar{\mu}$



Inverted basal friction coefficient, Q1 2009. Sliding law: $\boldsymbol{\tau}_b = -C\boldsymbol{u}$

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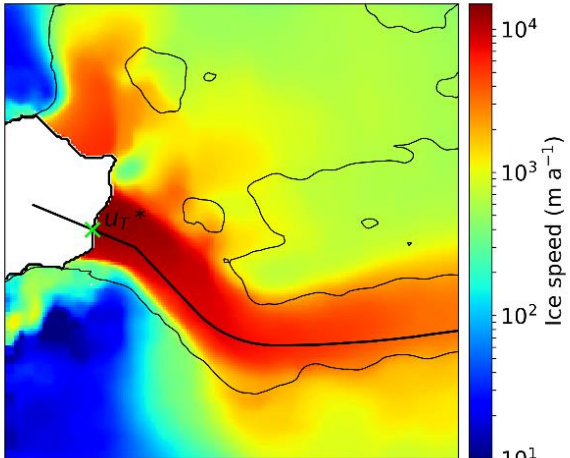
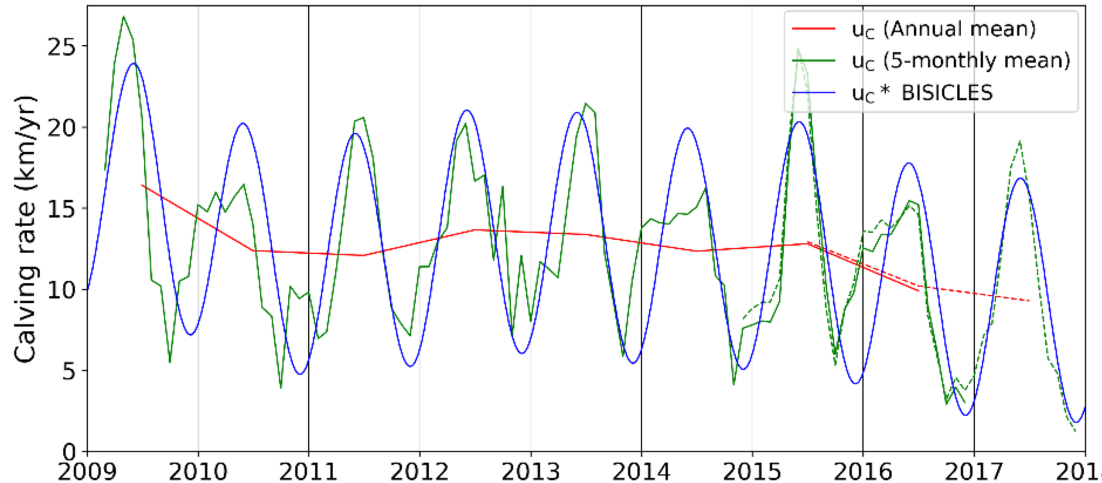
4. Calving rate application in BISICLES



Demonstration of scheme for spatial application of the calving rate



Applied calving rate timeseries. Mean annual (red), 5-monthly mean (green), sinusoidal fit to 5-monthly mean (blue)

- Spatial application of calving rate scaled according to the terminus velocity to avoid destroying regions of slower-flowing ice (* = measured on flowline):

$$\boldsymbol{u}_C(x,y) = \boldsymbol{u}_C{}^* \cdot \frac{\boldsymbol{u}_T(x,y)}{\boldsymbol{u}_T{}^*}$$

- Calving rate applied either annually or as a seasonal sin-wave oscillating about the annual mean

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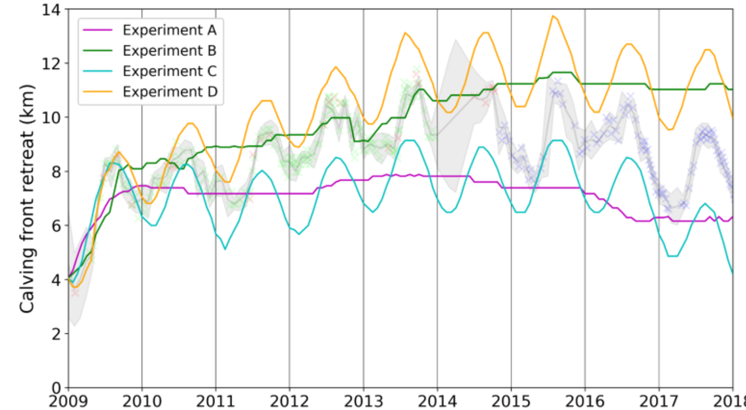
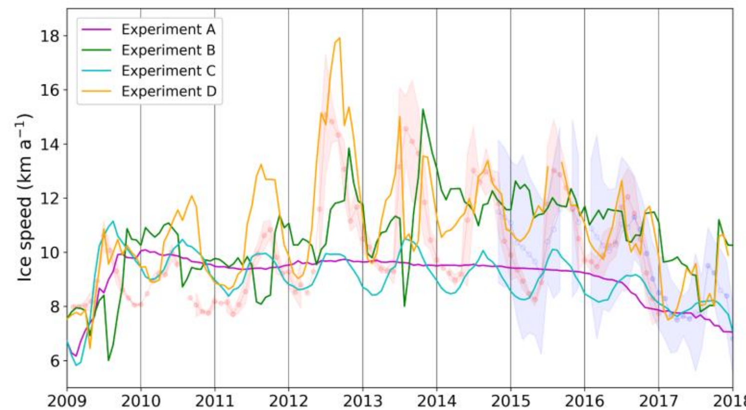
5. Decadal forward model runs

- 9 year forward model runs carried out 2009 - 2017.
- Experiments run for combinations of annual mean or sin-wave calving rate, and static or timeseries basal friction and ice rheology.
- Results compared to observations.
- BedMachine v3 [9] bathymetry and initial ice topography.
- Thinning rates from [10].
- Surface mass balance from RACMO [11].

Experiment	*φ* and *C* inputs	Calving rate
A	Long-term mean	Annual mean
B	Quarterly timeseries	Annual mean
C	Long-term mean	Sin wave
D	Quarterly timeseries	Sin wave



Modelled calving front advance/retreat for Experiments A to D (observed timeseries faded in background)



Modelled velocity for Experiments A to D (observed timeseries faded in background)

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6. Conclusions

- By applying a prescribed calving rate, we are giving the model half the picture.
- Model evolution broadly follows the observed decadal pattern when applying the annual mean calving rate – model flow adjusts well to the calving.
- Applying a quarterly timeseries of basal friction and ice rheology inputs improves the fit.
- Applying a seasonal oscillation in calving reproduces the annual advance-retreat cycle well.
- Our experiments neatly bracket the observed calving front position.

References

1. Rignot, E. and Mouginot, J., Geophysical Research Letters, 39, L11501 (2012)
2. Zhang, E., Liu, L., and Huang, L., The Cryosphere Discuss, tc-2019-14 (2009)
3. Haran, T., J. Bohlander, T. Scambos, and I. Joughin. 2017, updated 2018. MEaSUREs Greenland Monthly Image Mosaics from MODIS, NASA NSIDC
4. Lemos, A., Shepherd, A., McMillan, M., Hogg, A. E., Hatton, E., and Joughin, I., The Cryosphere, 12, 2087-2097 (2018)
5. Hogg, A., et al., A first look at the performance of Sentinel-1 over the West Antarctic Ice Sheet, FRINGE 2015, Frascati, Italy, 23-27 March 2015.
6. Cornford, S. L. et al., J. Comp. Phys, 232, 529-549 (2013)
7. Cornford, S. L. et al., The Cryosphere, 9, 1579-1600 (2015)
8. Nick, F. M. et al., Nat. Geosci., 2, 110–114 (2009)
9. Morlighem, M. et al., Geophysical Research Letters, 44, 11051-11061 (2017)
10. Khan, S. A. et al., Nature Climate Change, 4, 292-299 (2014)
11. Noël, B. et al., The Cryosphere, 12, 811-831 (2018)

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