Basal Melting beneath the Fimbul Ice Shelf

Mathilde Helbert | University of Bergen, Norway

Bjerknes Centre for Climate Research

Basal Melting

Ice shelf basal melting is the melting of the underside of ice shelves. This is one of the largest unpredictability in current and future sea-level modelling from the Antarctic Ice Sheet (IPCC, 2022). The basal melt rate is set by the sub-ice shelf–ocean boundary layer – a turbulent layer that regulates the transport of heat and salt to the ice. This layer is mainly subject to shear-driven turbulent heat transfer which is the main leader of the basal melting variability. [1] For a shear driven ice-ocean boundary layer, basal melting can be estimated by a three-equation parameterization consisting of the linearized freezing temperature expression and the balance between heat and salt fluxes at the ice-ocean interface [2]

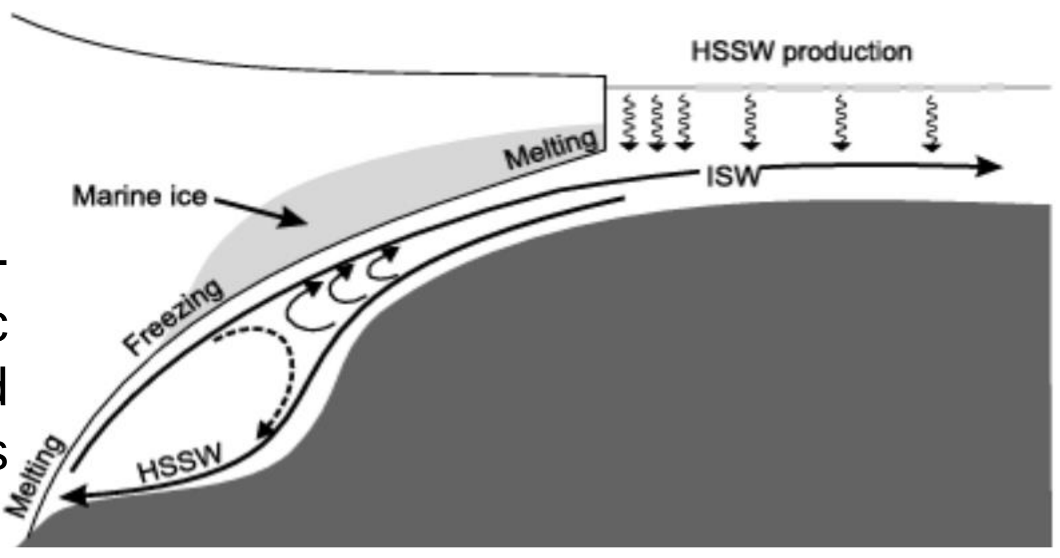
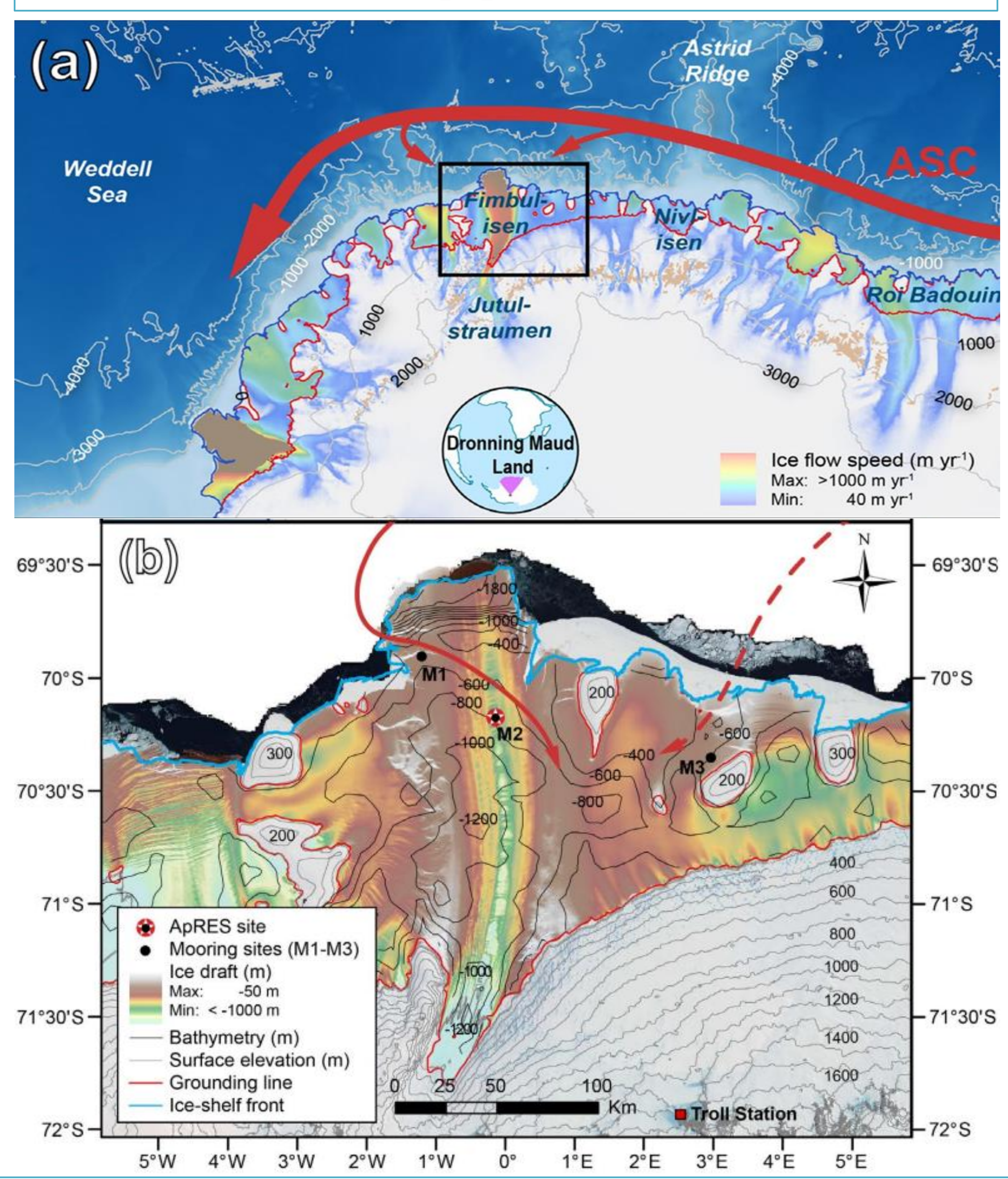


Figure 1. Two-dimensional schematic of the melting and freezing processes beneath FRIS

Fimbul Ice Shelf

Ice shelf: thick floating platform of ice that arises where the ice sheet is no longer thick enough to maintain contact with the seabed. [2]

Figure 2. (a) Dronning Maud Land coast, with ice fronts (blue line), grounding zone (red line), elevation contours with bathymetric features (grey lines), satellite derived ice speed and main flow paths of the warm-deep water in the Antarctic Slope Current (ASC), marked with red arrows. **(b)** Map over the study site, showing the ApRES and mooring locations (labelled dots) and the position of Troll research station (red square). Ice draft (color) and surface elevation (grey, labelled contours), bathymetry (labelled, black contours), and the grounding zone and ice front. The background image is Landsat image mosaic with some sea ice in front of the ice shelf. Grid coordinate system is WGS-84. The detailed ice topography around mooring site M2 is shown in the Supporting information. [1]



Three-equations parametrization for basal-melting a_b

Ablation rate at the ice ocean boundary

$$\rho_i a_b L_i = \rho_i c_i a_b (T_i - T_b) - \rho_w c_w u_* \Gamma_T (T_b - T_w)$$

- Amount of heat used for melting
- Heat conduction into the ice shelf (parameterized because the basal temperature gradient within the ice shelf is unknown)
- Turbulent heat flux through the oceanic boundary layer

Interfacial salinity

$$\rho_i a_b (S_b - S_i) = -\rho_w u_* \Gamma_S (S_b - S_w)$$

Sb is diagnosed from consideration of the salt balance at the phase change interface where the diffuse salt flux in the ice shelf is zero and the salinity of the ice Si is zero. [2]

The freezing temperature

$$T_b = \lambda_1 S_b + \lambda_2 + \lambda_3 P_b$$

The freezing point of seawater at the ice-ocean boundary is taken to be a linear function of both salinity and pressure. [2]

Basal melt rates measured at Fimbulsen

2003-2008: 0.9±0.2 m/yr; Rignot et al. (2013); Satellite

2009-2010: 0.84±0.01 m/yr; Langley et al.(2014); In-situ radar

2010-2018: 0.8±0.8 m/yr; Adusumilli et al. (2020); Satellite

2017-2021: 1.0±0.4 m/yr; Lindbäck et al.(2023); In-situ radar

Parametrizations & coefficients

- ρ is density
- L is latent heat of fusion
- c is specific heat capacity
- κ is thermal diffusivity
- T is temperature
- S is salinity
- P is pressure
- u_* is friction velocity
- λ_1 is liquidus slope
- λ_2 is liquidus intercept
- λ_3 is liquidus pressure coefficient
- Γ_T is turbulent transfer coefficient
- subscripts i, b, w, and f refer to ice, ice–ocean boundary, water, and the freezing point respectively

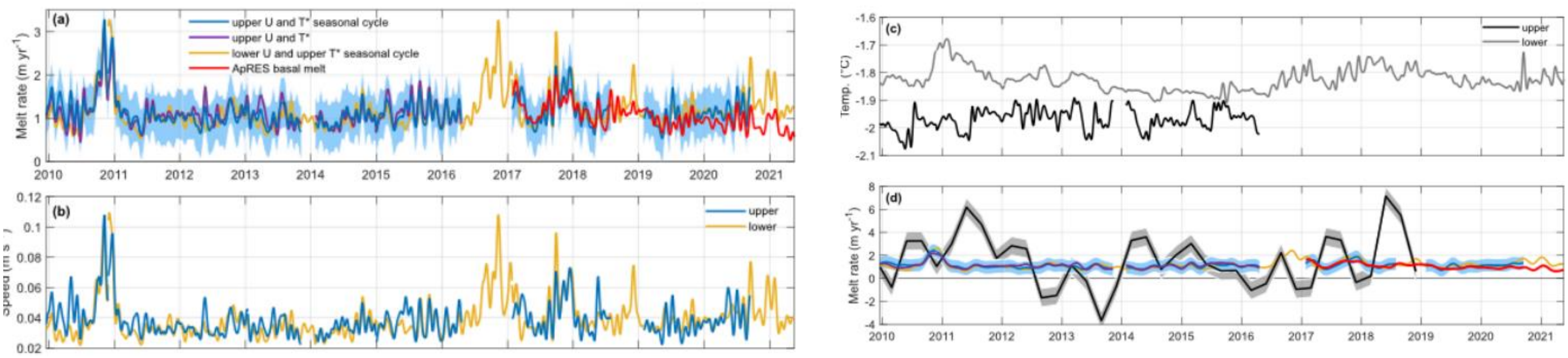


Figure 3. (a) Times series of basal melt rates from the parameterizations, and the ApRES (red line). The different parameterizations are based on the current speeds and mean monthly temperature cycle (2010–2016) from the upper sensor (blue line), current speed and temperature from the upper sensor (purple line), and the current speed from the upper sensor and temperature from the lower sensor (yellow line). The uncertainty of the parameterization with the best fit (blue line) is shown in light blue shading. **(b)** Ocean current strengths at M2 upper (blue) and M2 lower (yellow) sensor. **(c)** Ocean temperatures at M2 upper (black line) and lower (grey line) sensor. Time-series shown in (a-c) are 30-d low-pass filtered. **(d)** 90-d mean local satellite derived basal melt rates (black line), with uncertainty (grey shading). Parameterized and ApRES melt rates from panel (a) are also shown (90-d filtered). [1]

References

[1] K. Lindback, E Darelius, G. Mohold, I. Vankova, T Hattermann, J. Lauber, L. de Steur (2023). *Basal melting and oceanic observations beneath Fimbulisen, East Antarctica* Mittuniversitetet, University of Bergen, Norwegian Polar Institute, Los Alamos National Laboratory https://doi.org/10.22541/essoar.170365303.33631810/v1

[2] Jenkins, A., Nicholls, K. W., & Corr, H. F. J. (2010b). Observation and parameterization of 513 ablation at the base of Ronne Ice Ahelf, Antarctica. Journal of Physical Oceanography, 514 40(10), 2298–2312. https://doi.org/10.1175/2010JPO4317.1

CONTACT INFORMATION

Allégaten 55, NO-5007 Bergen | Tel: +47 55 58 98 03 | Fax: +47 55 58 43 30 | post@bjerknes.uib.no | **bjerknessenteret.no**