An improved and observationally-constrained melt rate parameterization for vertical ice fronts of marine terminating glaciers

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Motivation

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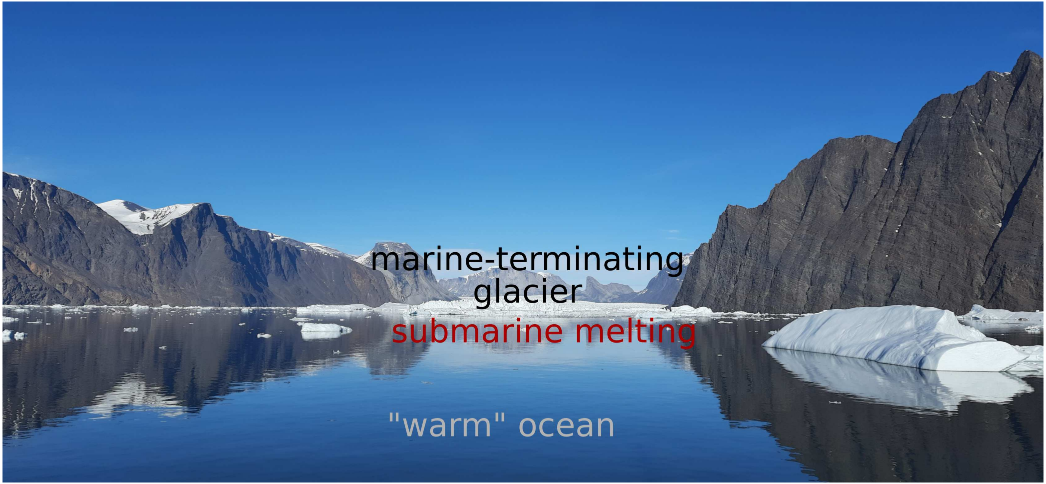

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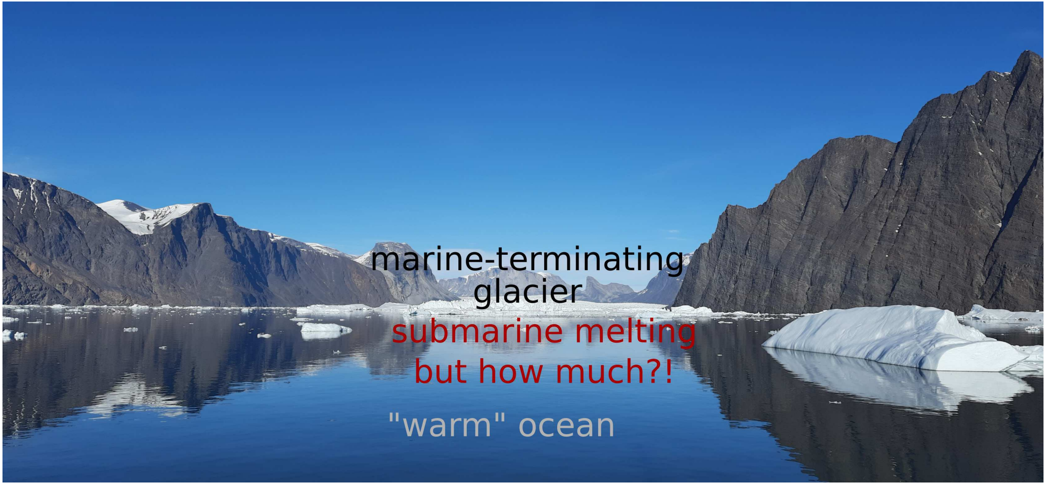
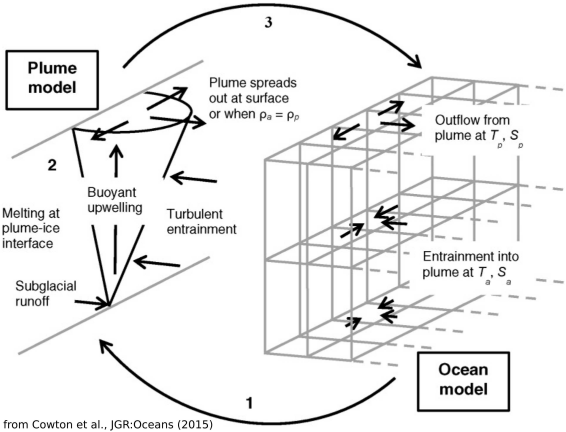

marine-terminating glacier
submarine melting
but how much?!
"warm" ocean

Starting point: Cowton et al., JGR:Oceans (2015) - "iceplume" package



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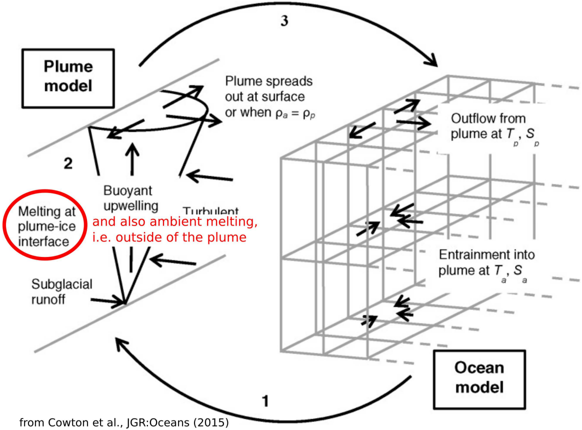

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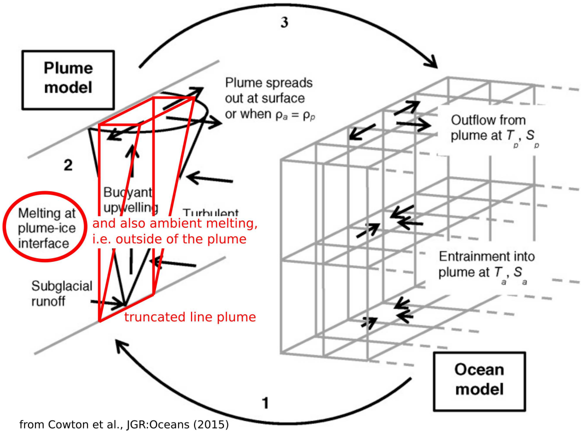

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Submarine melting - three equation model

$$\dot{m}(c_i(T_b - T_i) + L) = \gamma_T c_w (T - T_b)$$

$$\dot{m} S_b = \gamma_S (S - S_b)$$

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

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Unknowns: melt rate $\dot{m}$, interface temperature and salinity T_b, S_b.

Known/Input: ambient temperature and salinity T, S, depth z.

Well-constrained parameter: specific heat capacities of ice c_i and water c_w, latent heat of melting ice L, empirical constants $\lambda_{1,2,3}$.

Critically unconstrained parameter: thermal and haline transfer velocity γ_T, γ_S.

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Kerr and McConnochie (2015): $\gamma_S = 0.07\gamma_T$ (lab experiments)

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Critically unconstrained parameter: thermal transfer velocity γ_T.

γ_T for AMBIENT MELTING

State of the art:

$\gamma_T = \Gamma_T C_d^{0.5} u$ (Ronne Ice Shelf data, Jenkins et al., 2010),
and minimum $u = u_{bg} =\sim 0.1$ m s^{-1} (e.g. Cowton et al., 2015).

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Issues:

- Applicability to vertical fronts questionable, actually produces melt rates that are two orders of magnitude too low (Jackson et al., 2020).
- The "background velocity" u_{bg} has no physical meaning, model results sensitively depend on it.
- Overall too many unconstrained parameters.

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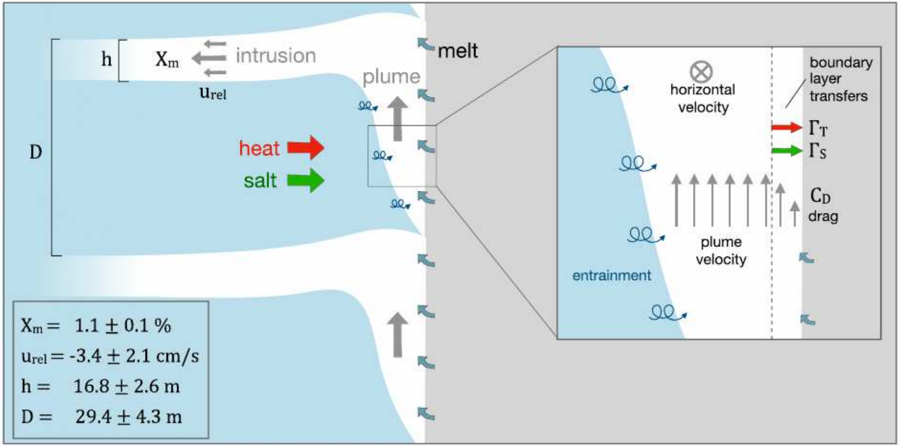
New approach:

$$\gamma_T = \gamma_T^*$$

- Justified if convection dominates over frictional effects, i.e. low velocity regimes.
- One single free parameter, can be constrained with recent observations from LeConte glacier (Jackson et al., 2020).

γ_T for AMBIENT MELTING

Observations from Jackson et al., (2020):



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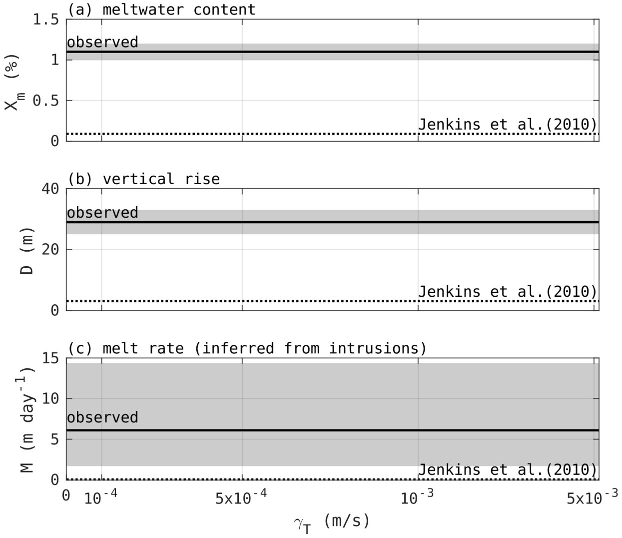

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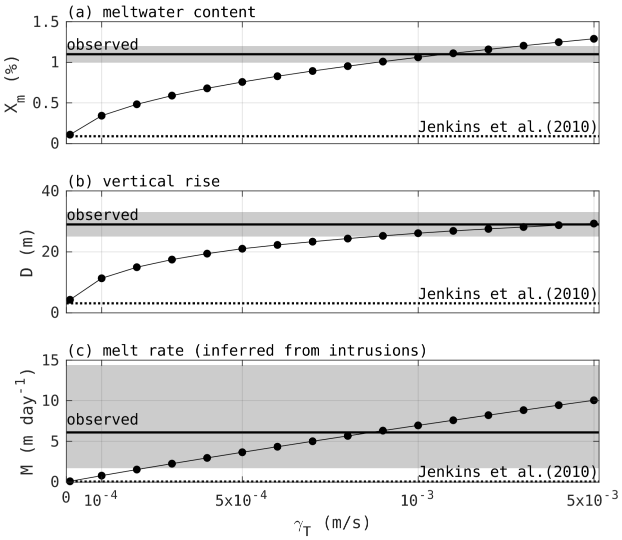

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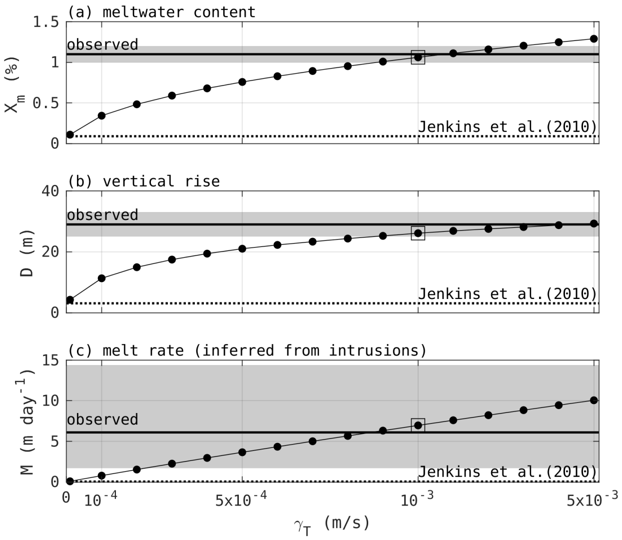
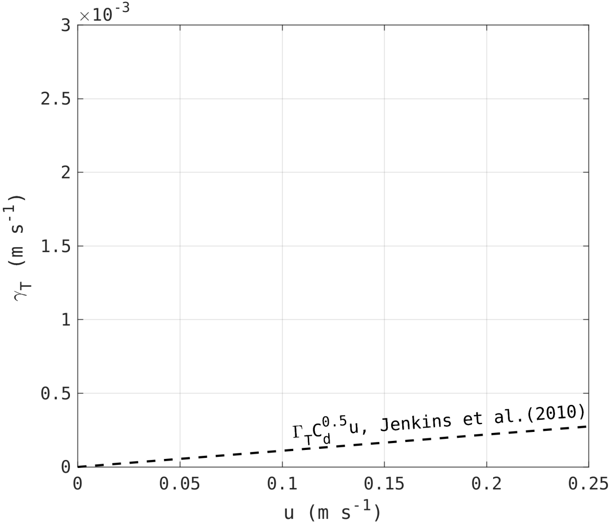


Best fit: $\gamma_T^* \sim 10^{-3}$ m s^{-1}

γ_T also for PLUME MELTING



Jenkins et al. (2010): shear-driven BL, parameter scaled with obs from Ronne Ice Shelf.

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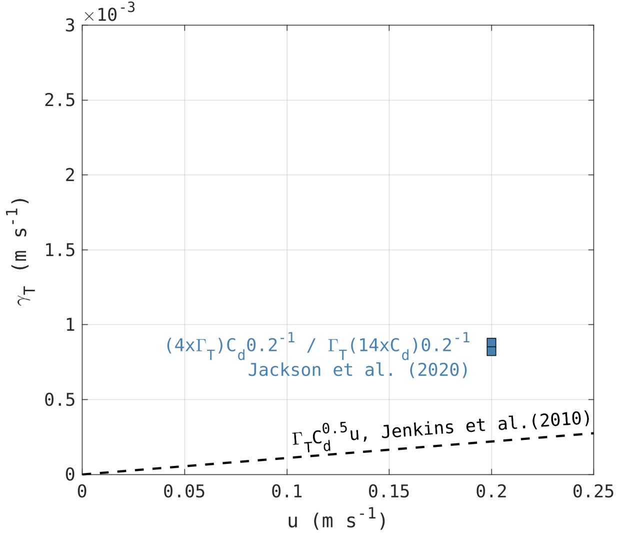

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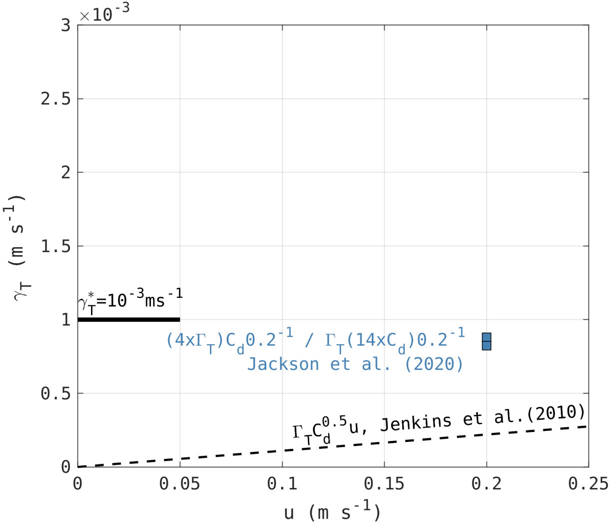

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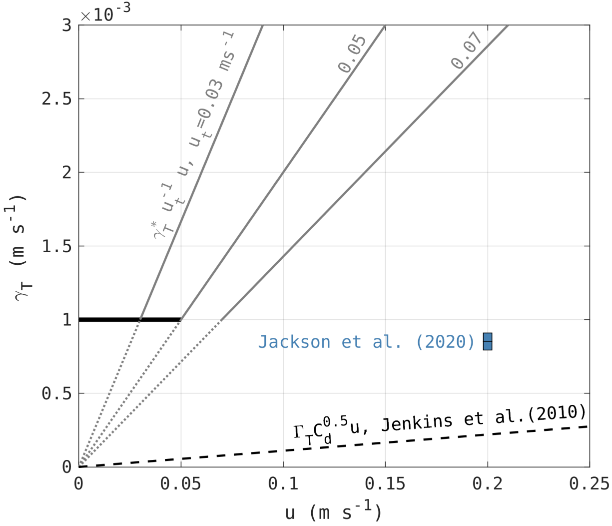

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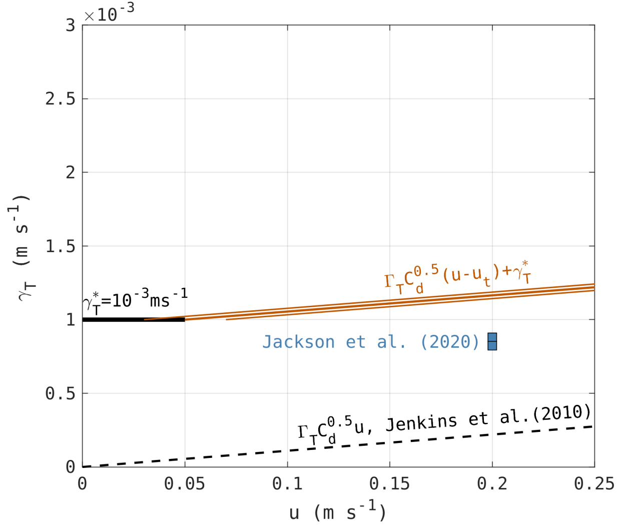
Extension to shear-driven regime ($u > u_t$):
Option A: force zero intercept - bad!

γ_T also for PLUME MELTING



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Extension to shear-driven regime $(u > u_t)$:
Option B: retain slope from Jenkins et al. (2010), linear superposition - better!

Summary: The new melt rate parameterization

$$\gamma_T = \begin{cases} \gamma_T^* & u \leq u_t \\ \Gamma_T C_d^{0.5}(u - u_t) + \gamma_T^* & u \geq u_t, \end{cases}$$

$\gamma_T^* \sim 1 \times 10^{-3}$ (constrained with obs from Jackson et al., 2020)

$u_t \sim 0.05$ m s^{-1} (McConnochie and Kerr, 2017)

$\Gamma_T \sim 2.2 \times 10^{-2}$, $C_d \sim 2.5 \times 10^{-3}$ (Jenkins et al., 2010)

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Can be used with:

- observed fjord T,S profiles, glacier geometry, and subglacial discharge data.
- a fjord-resolving ocean model $\rightarrow$ exciting next presentation by Mike!

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Key Points:
- Convective instabilities may govern

Thank you for listening!

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