Towards an improved Antarctic ice shelf basal melt parameterisation

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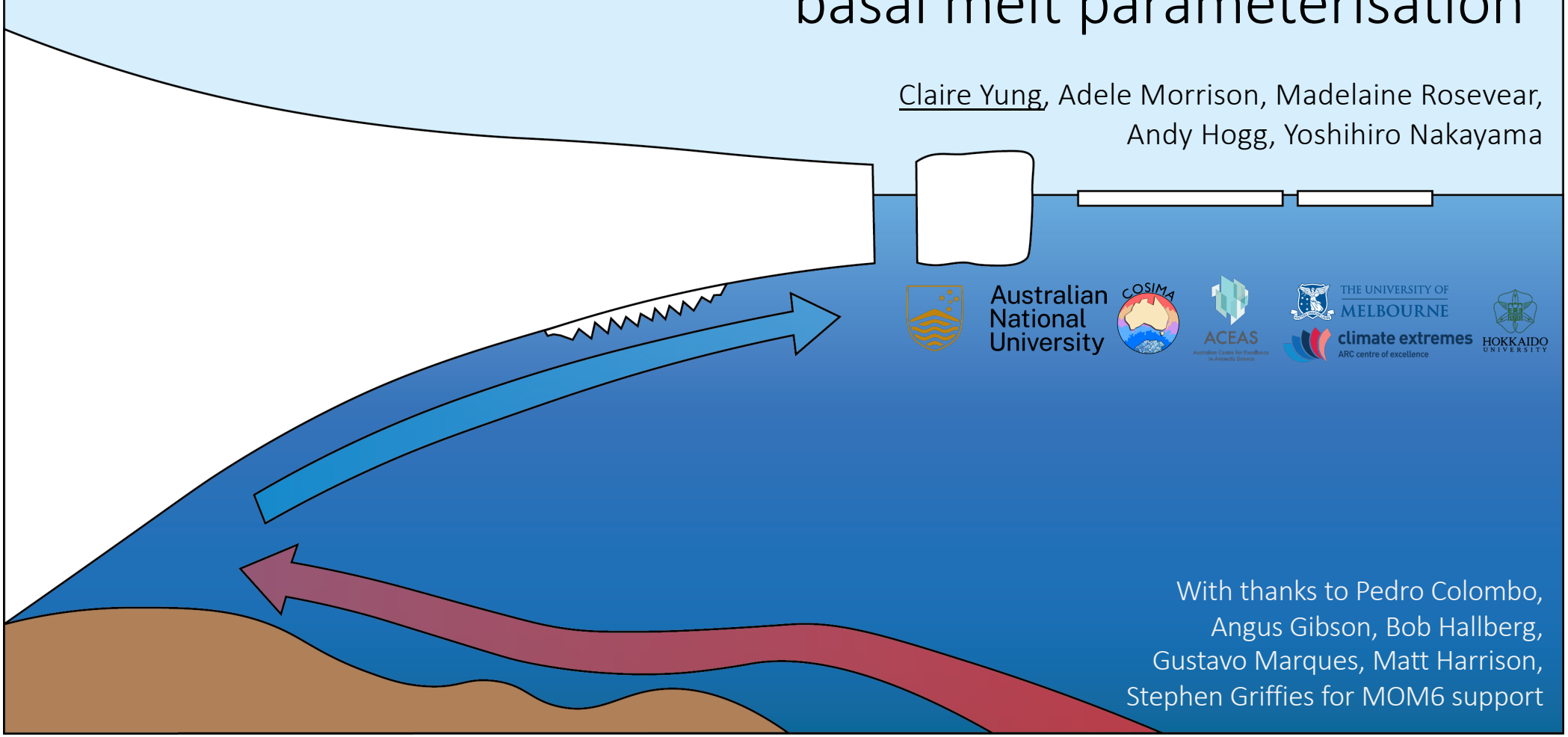

With thanks to Pedro Colombo,
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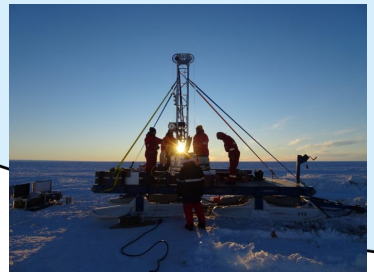
Gustavo Marques, Matt Harrison,
Stephen Griffies for MOM6 support

Antarctic ice shelf basal melting is important, but hard to observe



Credit: Sophie Berger

ice flow

refreezing

iceberg calving

sea ice

Credit: Jason Gobat/University of Washington

basal melting

Ice Shelf Water

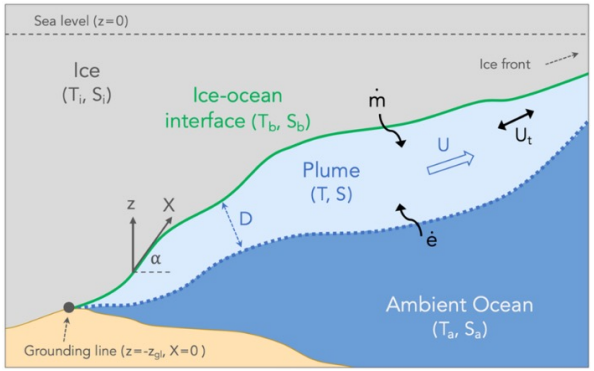
ice shelf cavity

grounding line

Circumpolar Deep Water

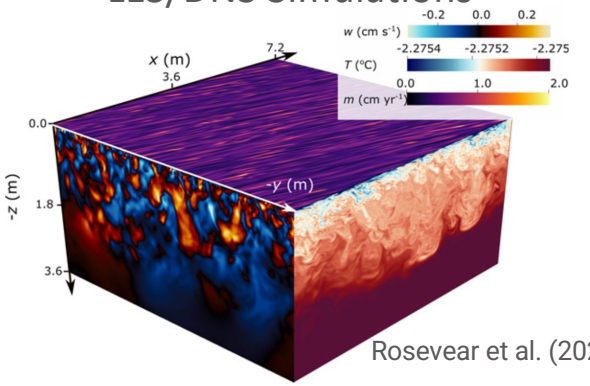
Ice shelf models of different scales and complexity

1D Plume Models



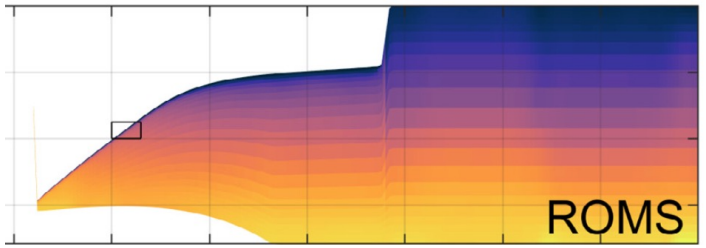
Anselin et al. (2023)

LES/DNS Simulations



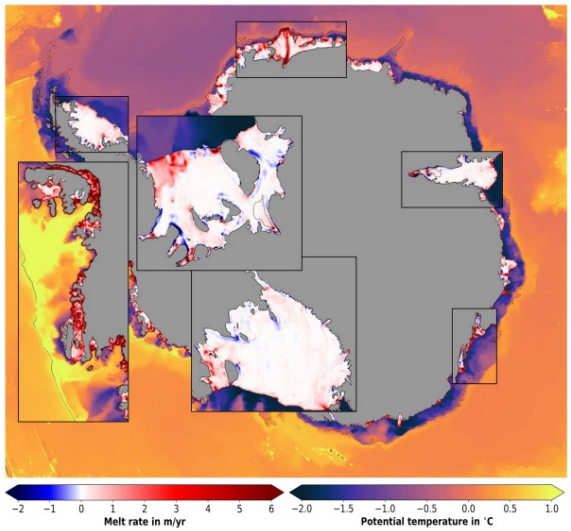
Rosevear et al. (2022)

Idealised Ocean Models



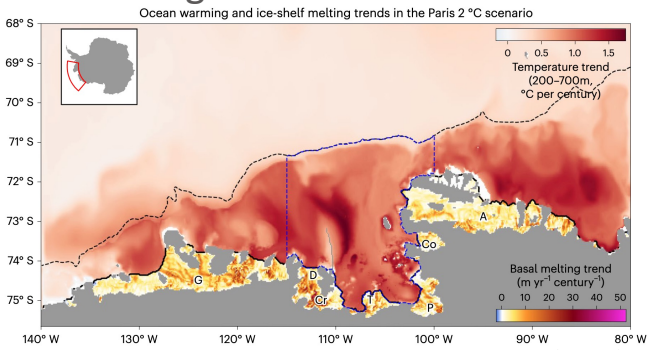
Gwyther et al. (2020)

Pan-Antarctic Ocean Models



Richter et al. (2022)

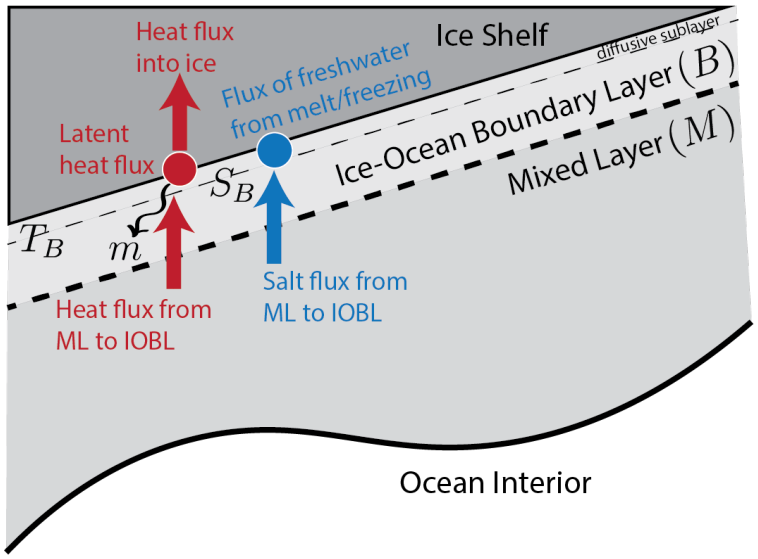
Regional Ocean Models



Naughten et al. (2023)

Basal melting parameterisations

Three-equation parameterisation (conservation of heat, salt and equation of state) approximates as:



Melt (m/yr)

Thermal driving

$$\dot{m} \propto \Gamma_T (T_M - T_B) u_*$$

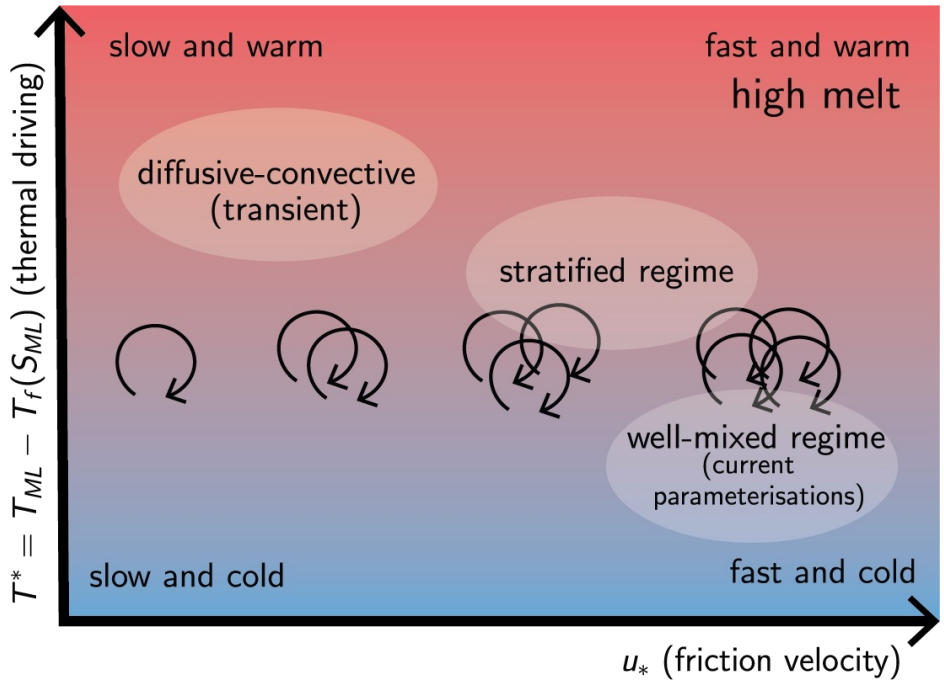
friction velocity

transfer coefficient of heat transport from mixed layer to ice

However….

- Transfer coefficients Γ_T and Γ_S are not well constrained
- Often tuned to cold Filchner-Ronne ice shelf (Jenkins et al. 2010)
- Overestimate melting by a factor of 2 to 70 (Rosevear et al. 2022)

….because Antarctic ice shelves are not all the same.



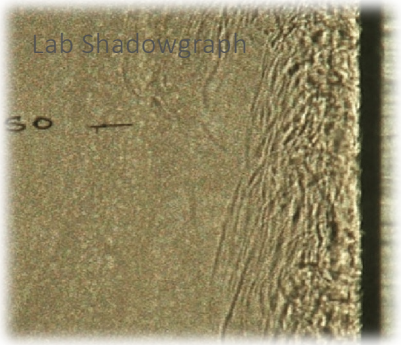
Lab and LES/DNS studies can inform basal melt parameterisations

$$\text{melt} \propto \sin^{2/3}\theta$$ ← Basal slope

$$\text{melt} \propto (T_\infty - T_b)^{4/3}$$

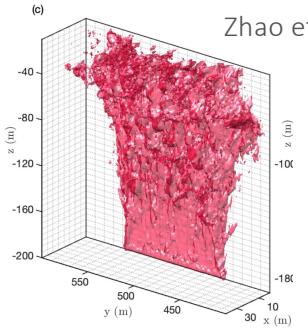
Far-field ocean temperature

(lab-based experiments of sloping ice, McConnochie & Kerr, 2018)



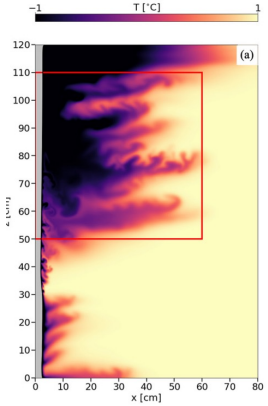
LES of vertical plume

Zhao et al. (in review)



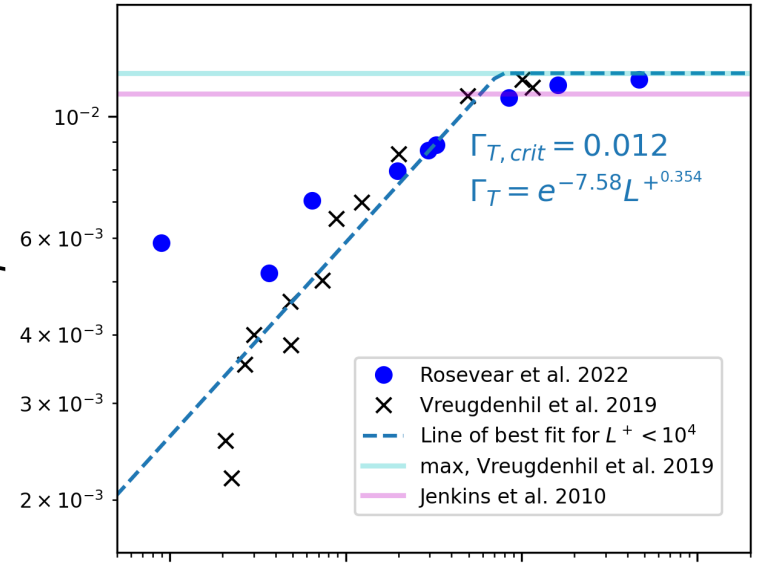
DNS of double diffusion at vertical ice face

Wilson et al. (2023)



LES studies inform parameters

Vreudgenhil et al. (2019) and Rosevear et al. (2022)

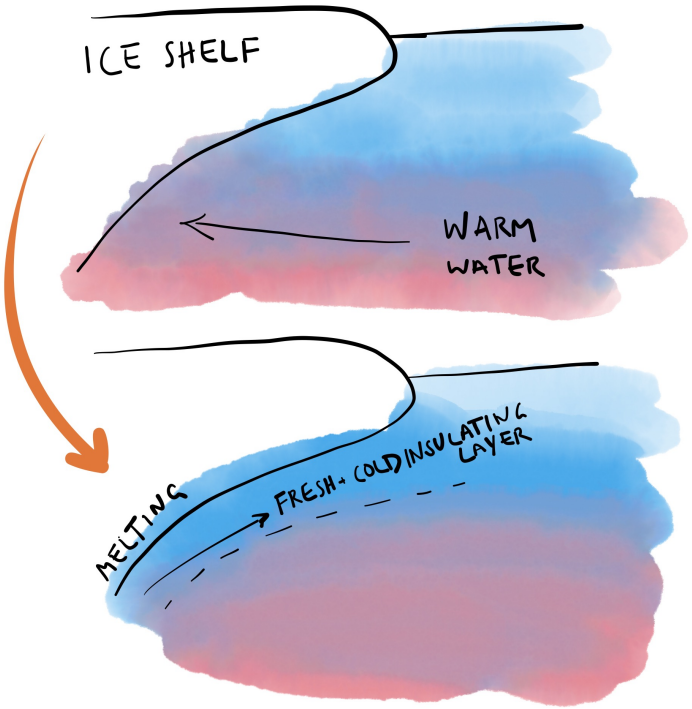


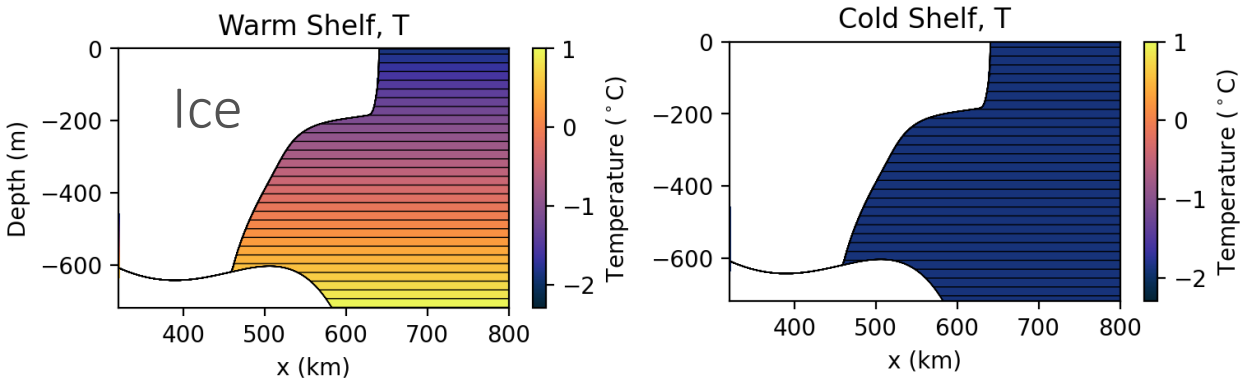
$$L^+ \propto \frac{u_*^4}{Buoyancy}$$

$$m \propto \Gamma_T (T_M - T_B) u_*$$

Viscous Obukhov Scale

Stratification suppression of melting – R22 parameterisation

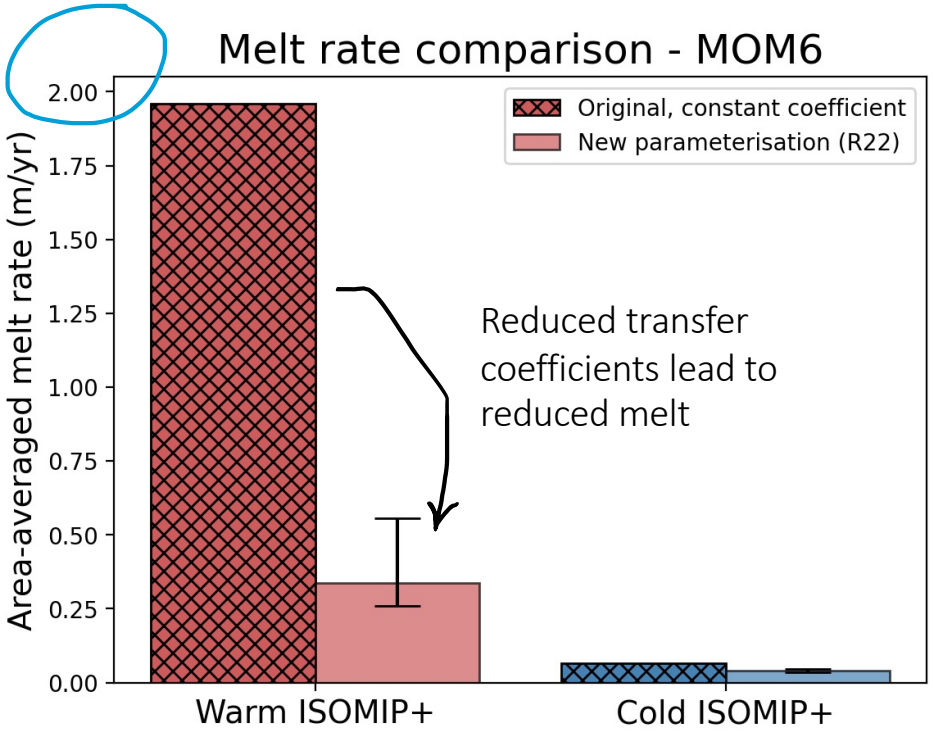


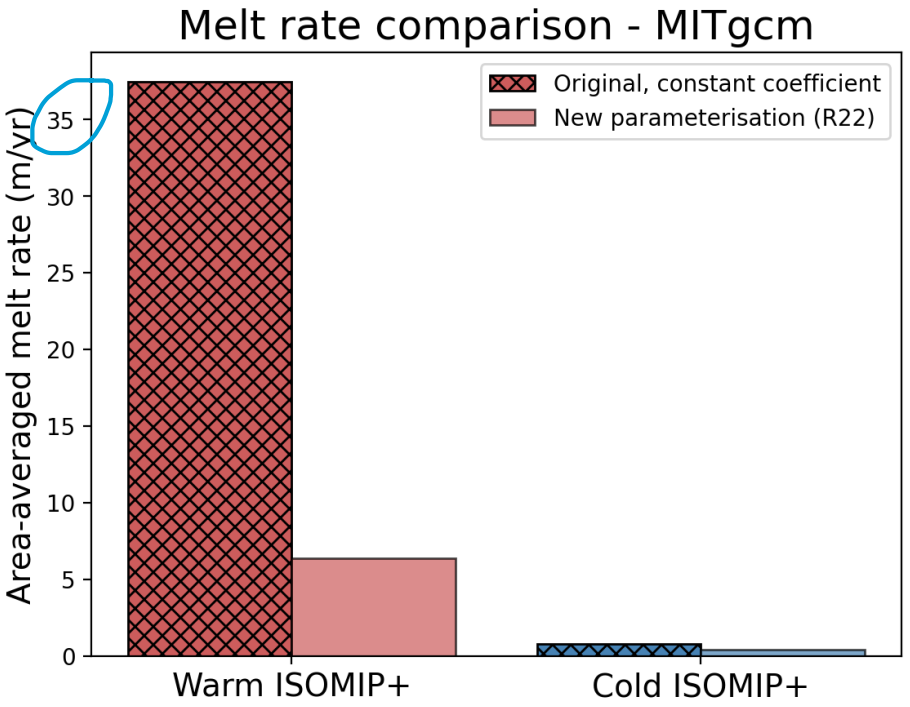


R22 parameterisation: $\Gamma_{T,S} = f(u_*, Buoyancy)$

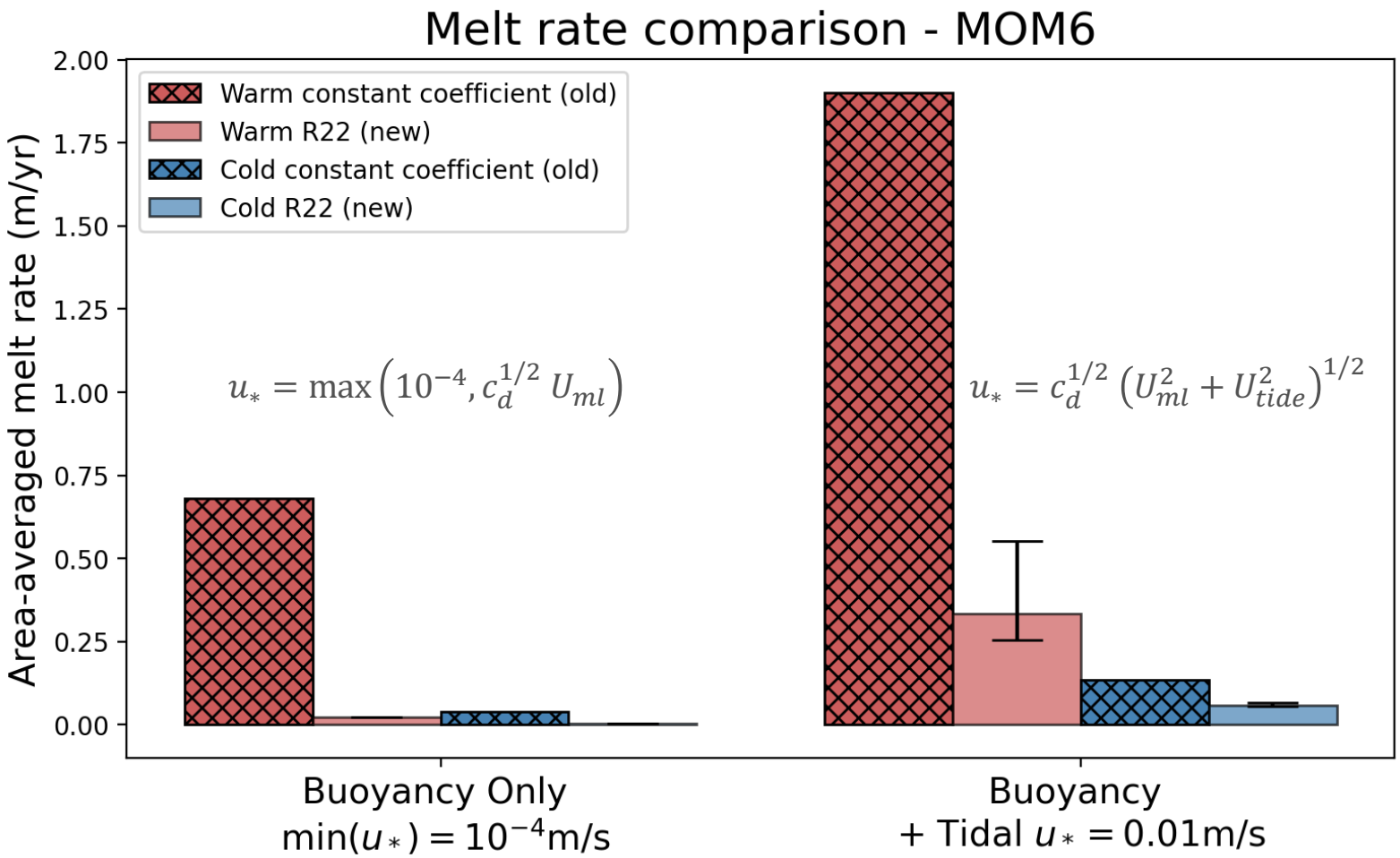
- **MOM6:** isopycnal layered coordinate with a bulk mixed layer (Stern et al., 2017, 2019)
- **MITgcm:** zstar (Losch, 2008, Y. Nakayama)
- **Idealised ISOMIP+ domain** (Asay-Davis, 2016)

Modified melt rate ratios are consistent between models

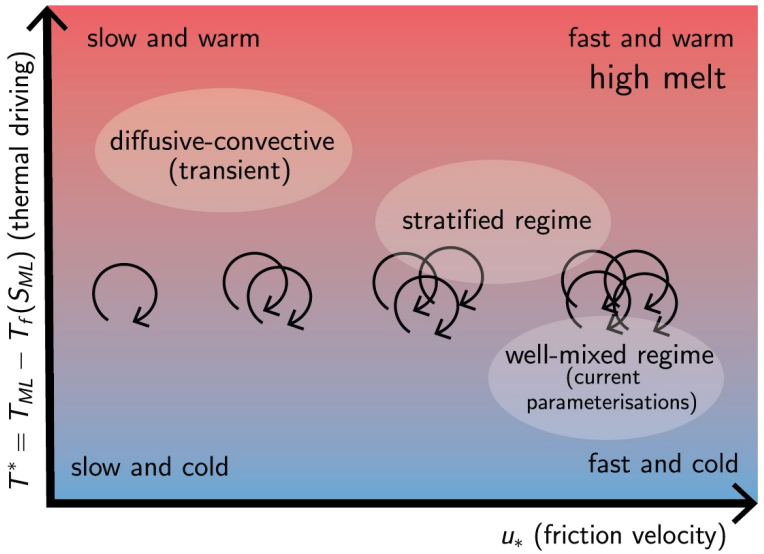


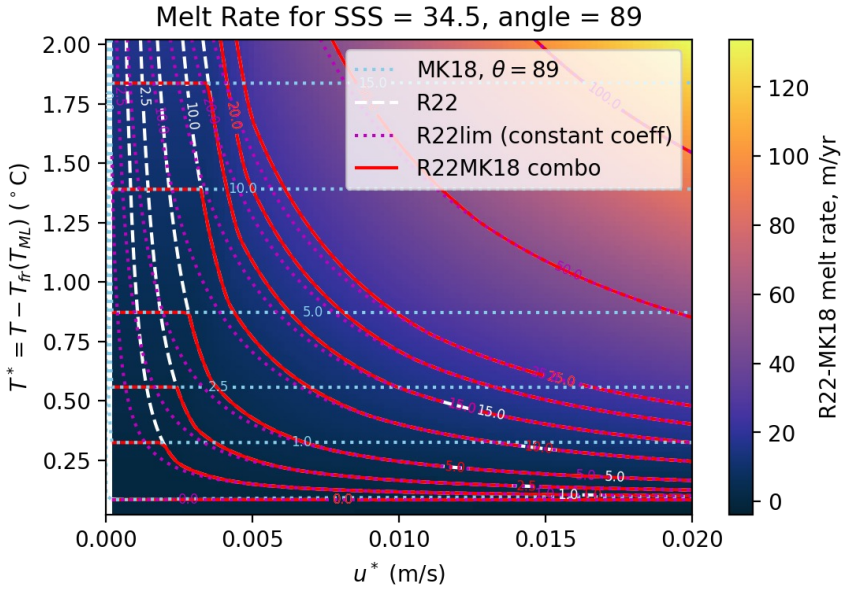


Sensitivity to prescribed tidal velocity or minimum friction velocity



What do we do at the warm, quiet limit?



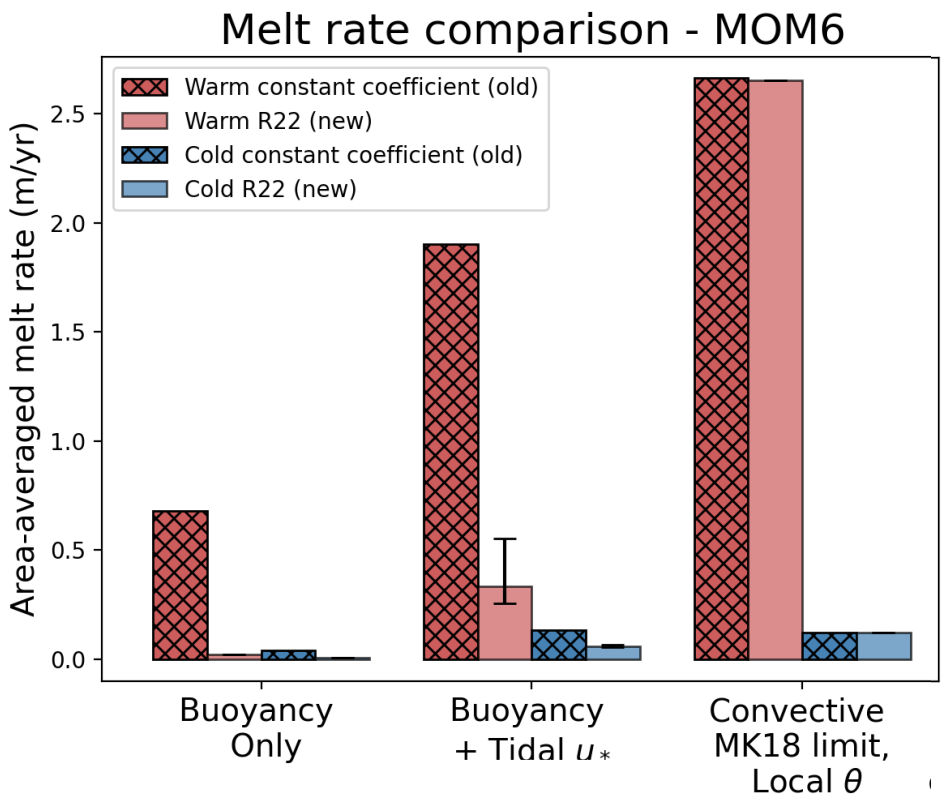


We want nonzero melt rate even if the mixed layer velocity = 0

- Minimum u_* ~ molecular diffusivity
- Tidal u_* offset

- Smoothly transition to a velocity independent parameterisation (e.g. Schulz (2022) for vertical ice fronts)
  - Use McConnochie and Kerr (2018) lab-based results, where effective transfer velocity $\gamma^*_{T,S} = \mathrm{f}(\theta)$ (and weakly a function of S and T)

Regime-based parameterisation result



- Basal melt parameterisation continuously transitioning between shear-driven (original) regime, stratified regime (R22) and convective regime (MK18)

- Melt rates controlled by convective regime in ISOMIP+ without prescribed tidal u_*.

- Ongoing challenges to

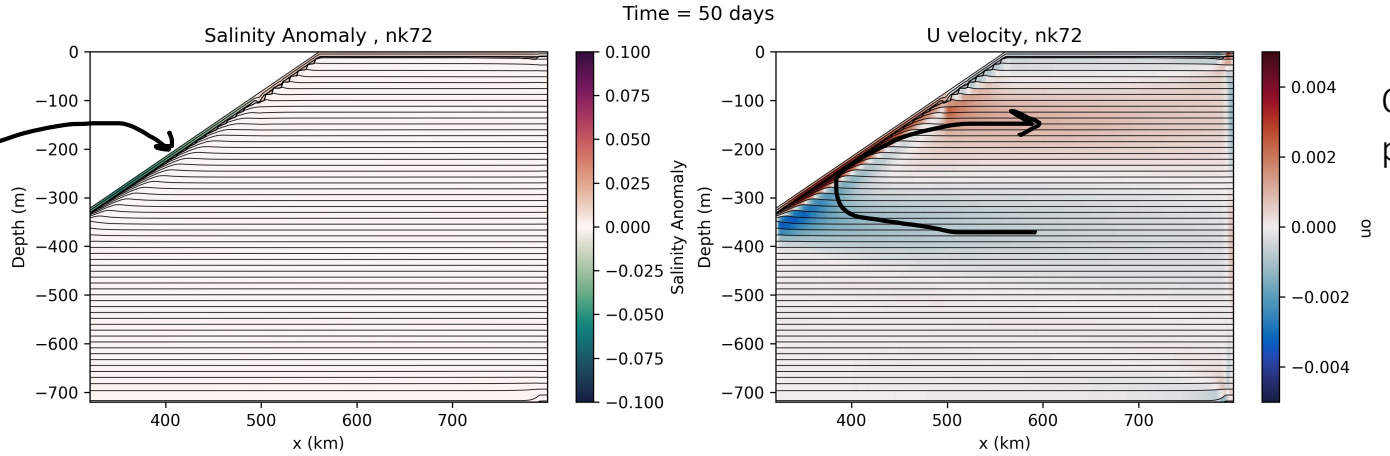
1. Extend a LES/lab-based regime-aware melt parameterisation to the large scale
2. Test the parameterisation in a variety of regimes – perhaps ISOMIP+ is not suitable

2D Model

Returning to the vastly different melt rates between MOM6 and MITgcm in ISOMIP+ (with a given transfer coefficient):

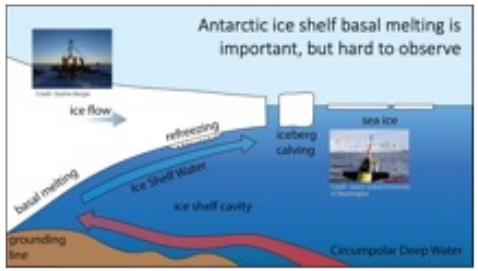
- Huge challenge for modellers to simulate a realistic Antarctica
- Vertical coordinates and vertical resolution, as well as sampling of T,S and meltwater distribution depth, significantly impact melt rates (Gwyther, 2020)
- Ongoing work: idealised, 2D configurations
- With Bob Hallberg, working on eliminating spurious currents in MOM6 ice shelves with ALE

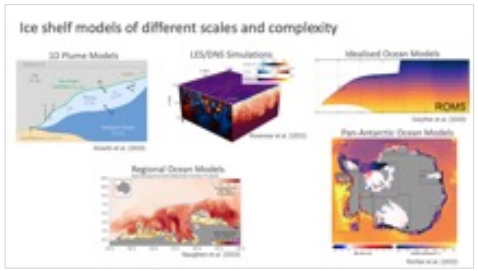
Cooling and freshening of surface layer

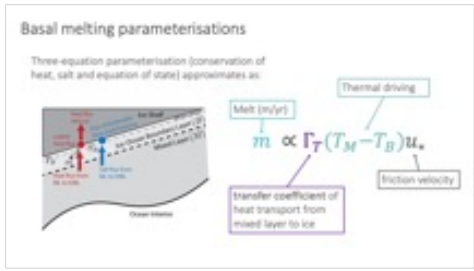


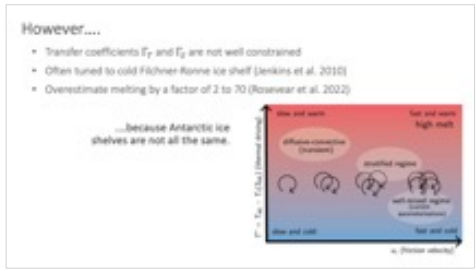
Overturing ice pump circulation

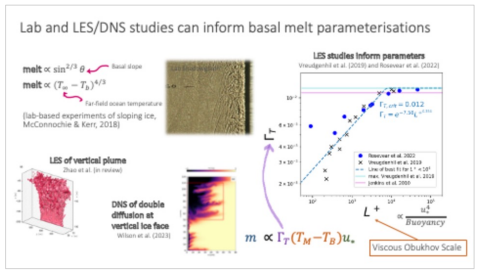
Thank you

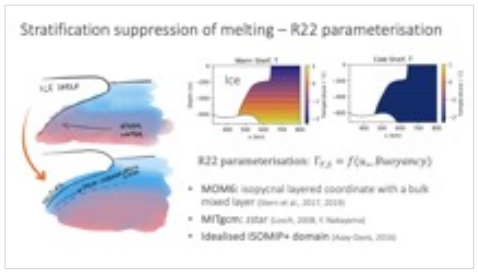


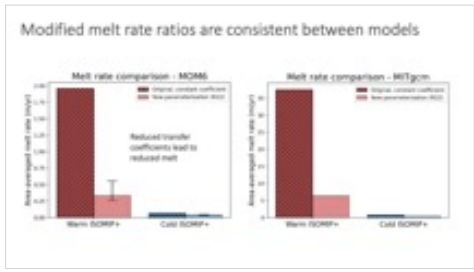


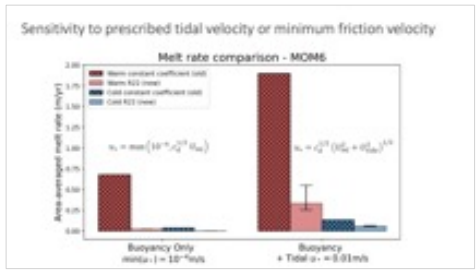


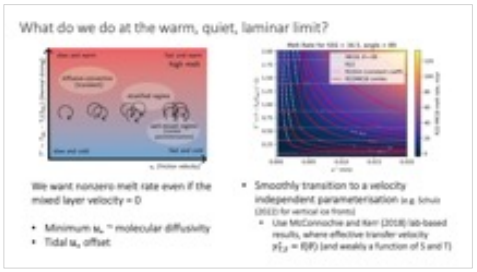


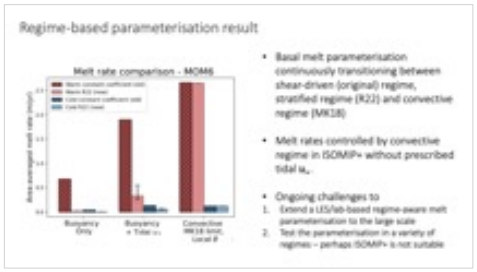


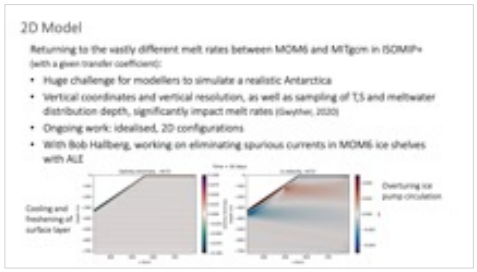












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