# An assessment of basal melt parameterisations for Antarctic ice shelves









and Nicolas Jourdain, Ronja Reese, Adrian Jenkins, Pierre Mathiot



https://tc.copernicus.org/ preprints/tc-2022-32/



This work is part of

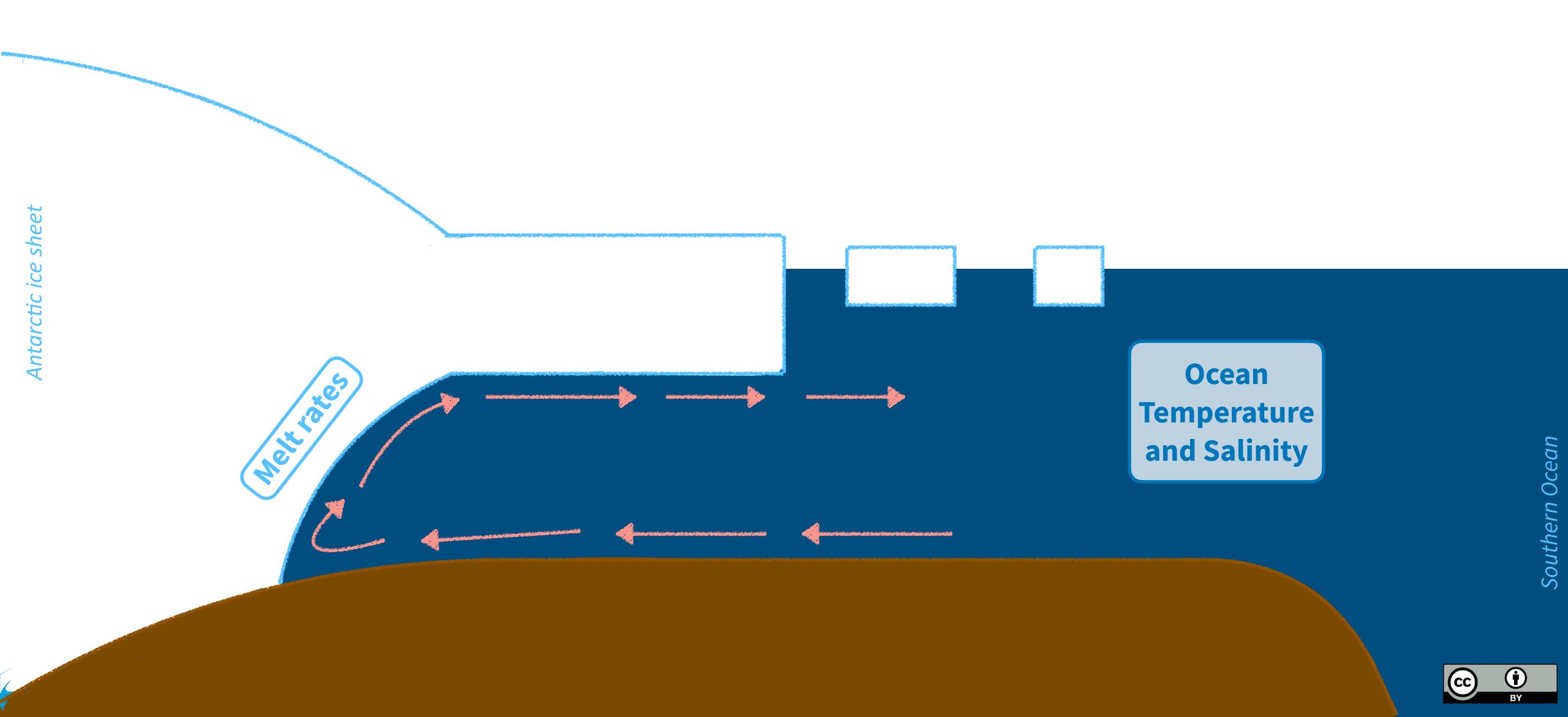




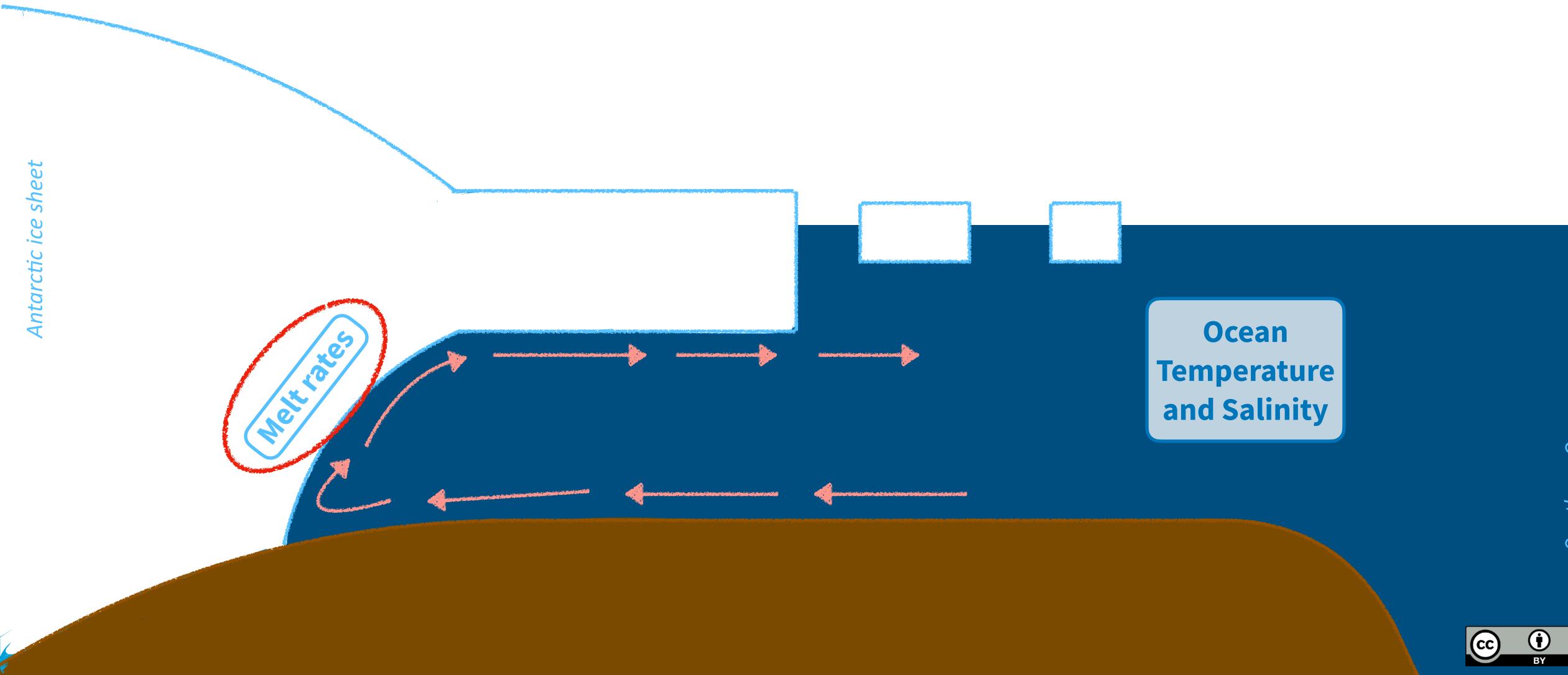


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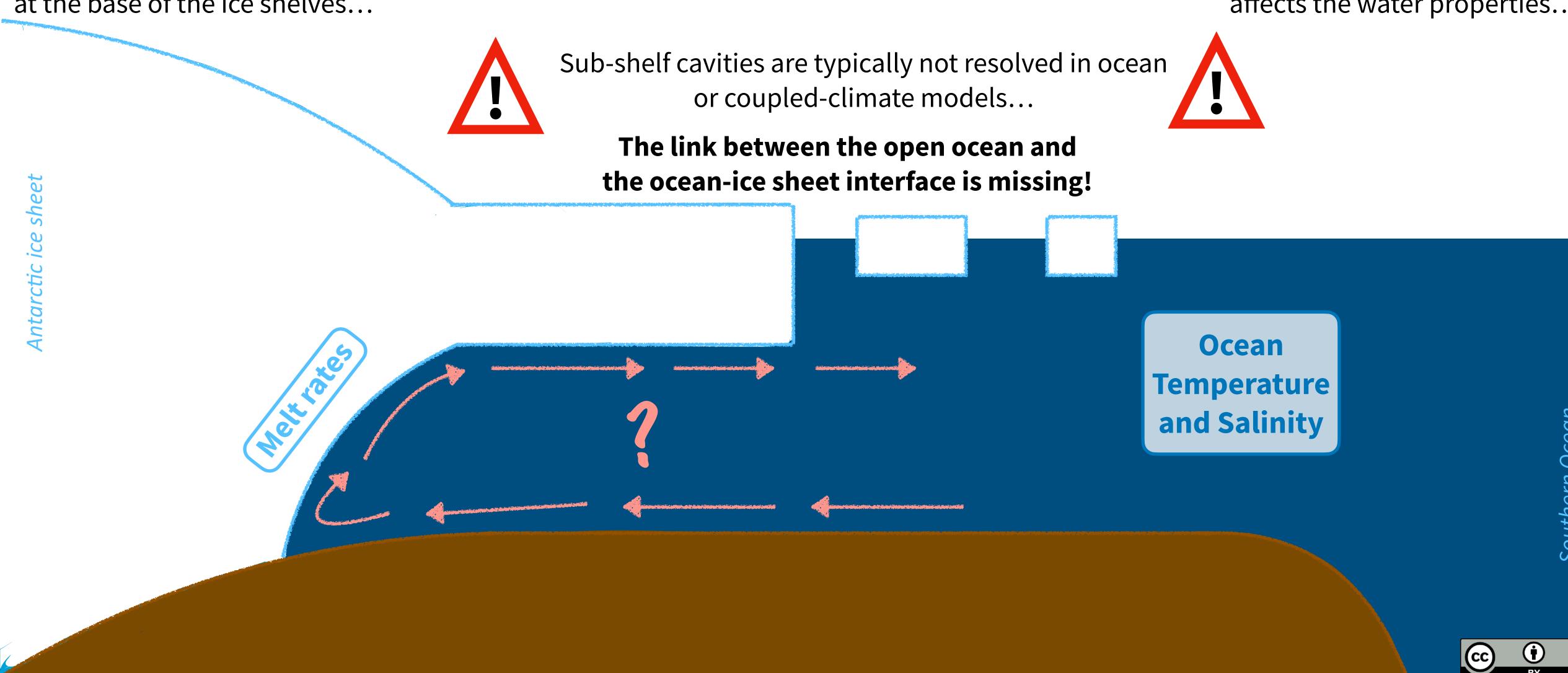
Ice-sheet models need information about ocean-induced melt at the base of the ice shelves...



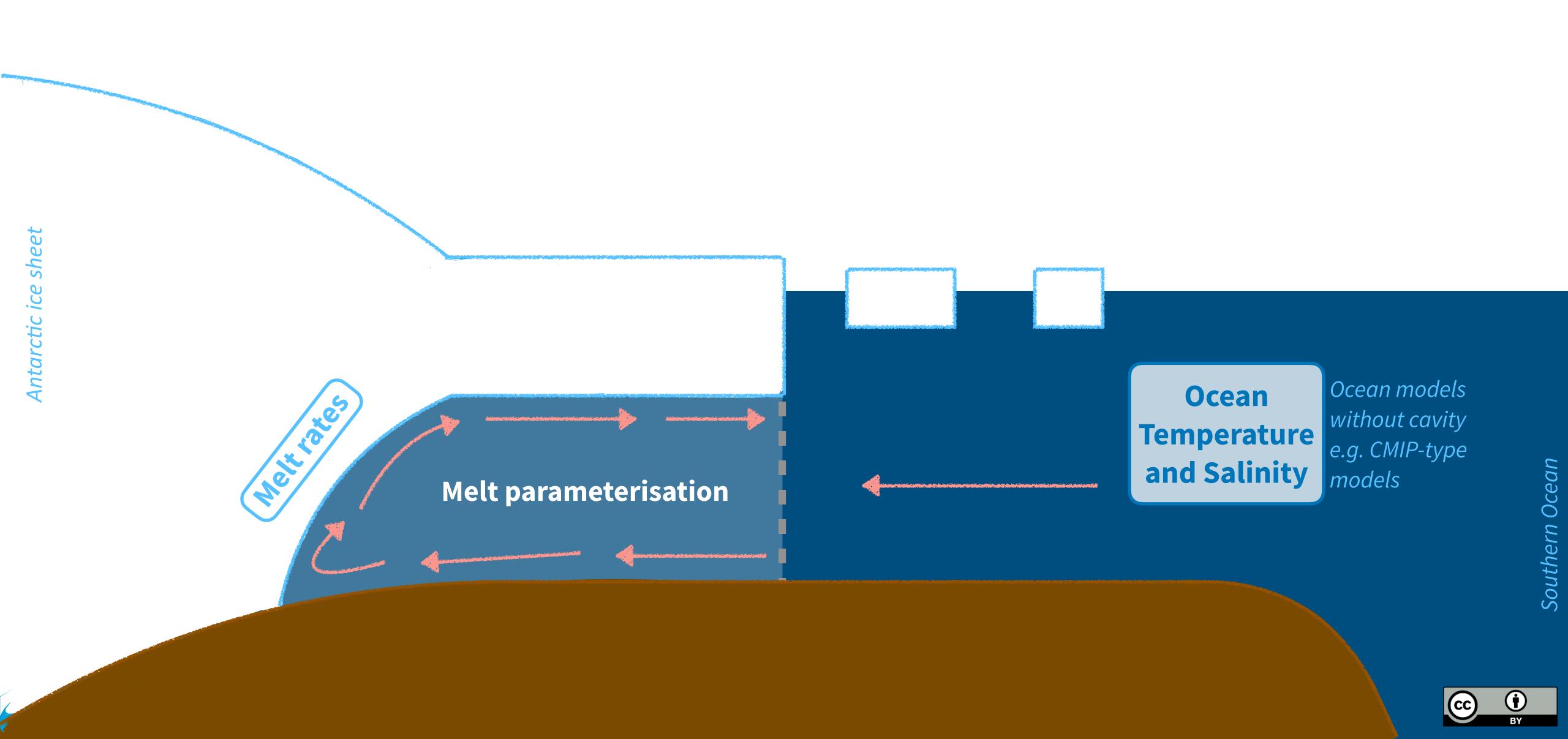
Ice-sheet models need information about ocean-induced melt Ocean models need information about the melt as it at the base of the ice shelves... affects the water properties... Ocean **Temperature** and Salinity

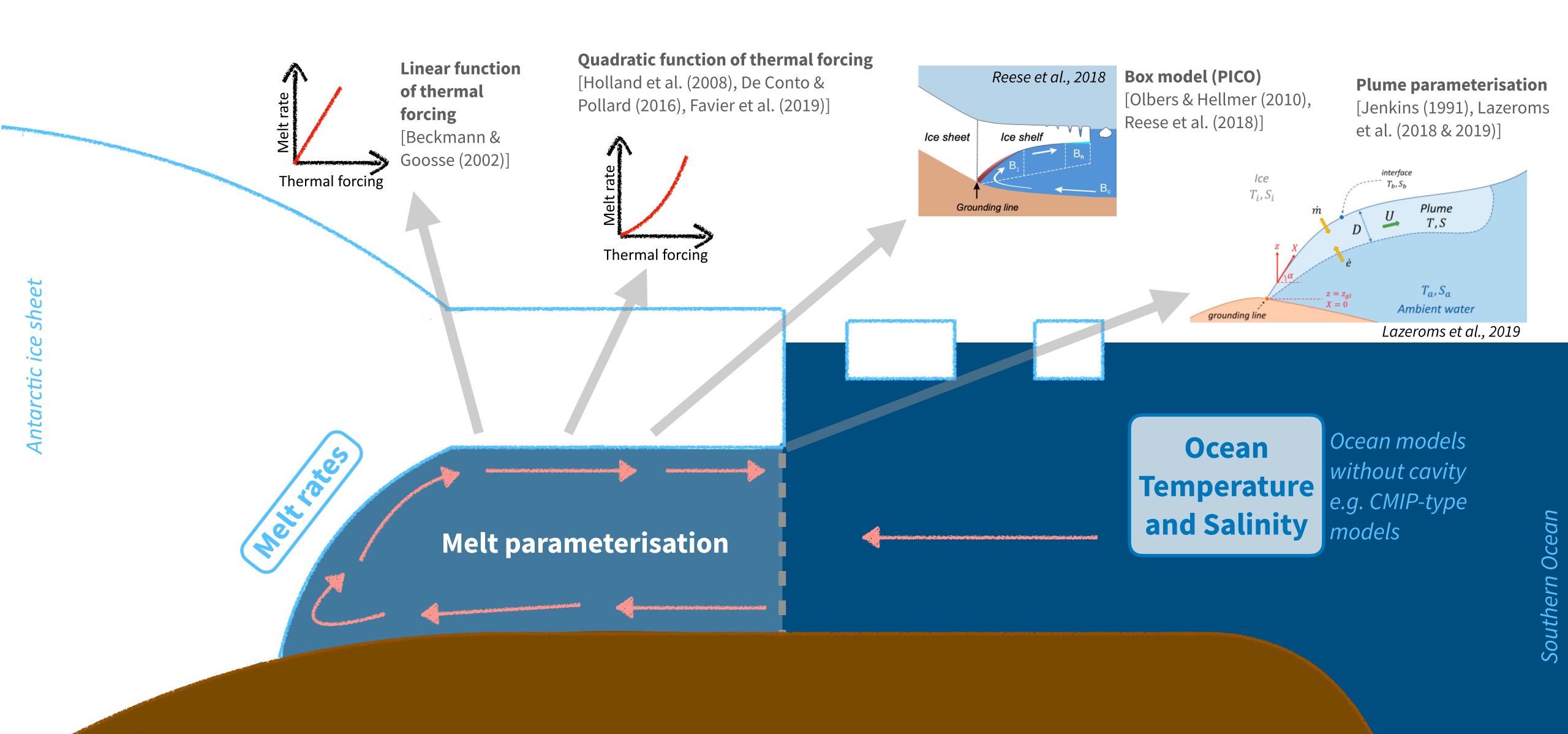
Ice-sheet models need information about ocean-induced melt at the base of the ice shelves...

Ocean models need information about the melt as it affects the water properties...

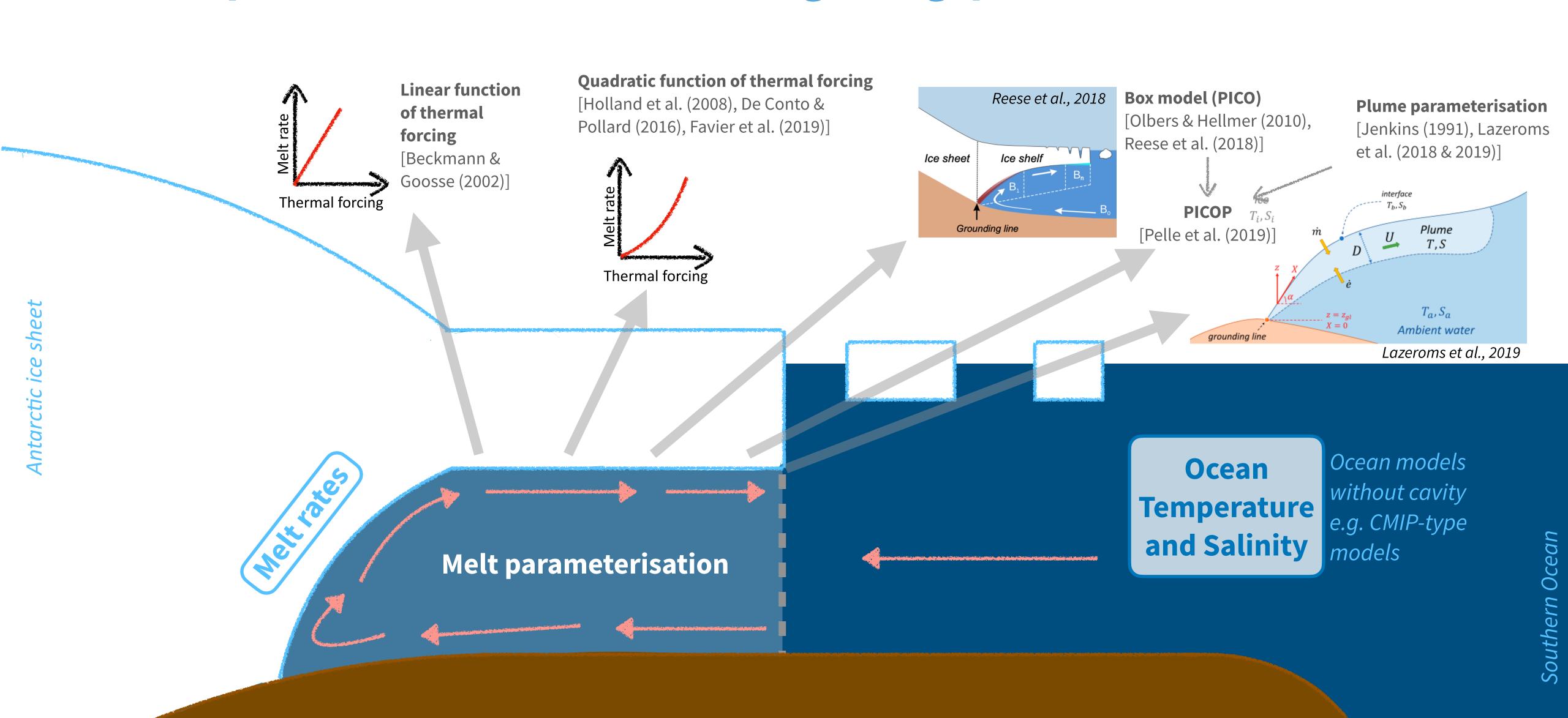


#### Basal melt parameterisations exist to bridge the gap

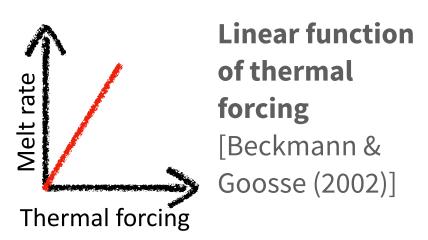




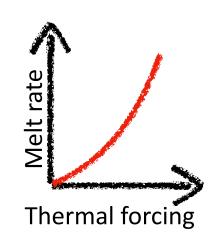


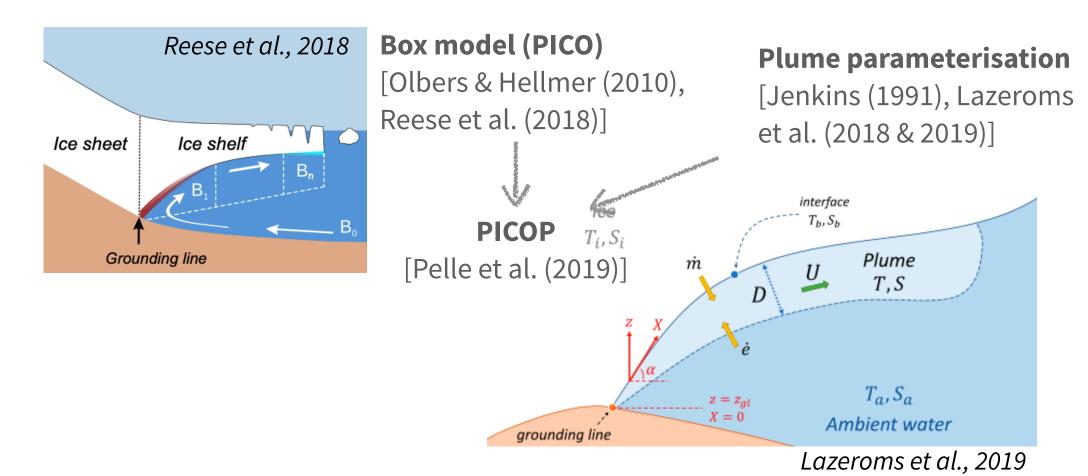


#### The evaluation of these parameterisations is challenging...



Quadratic function of thermal forcing [Holland et al. (2008), De Conto & Pollard (2016), Favier et al. (2019)]



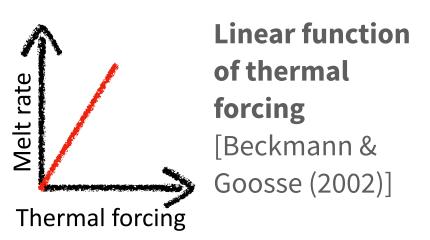


#### **Evaluation with observations**

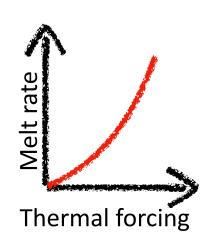


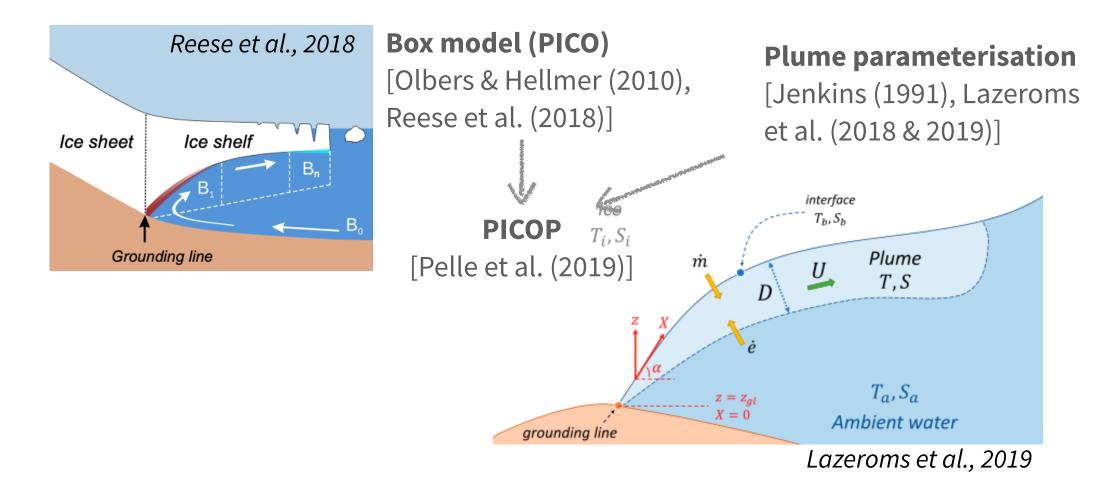
In-situ observations of input oceanic properties are sparse Satellite estimates of melt rates are uncertain

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#### **Evaluation with observations**



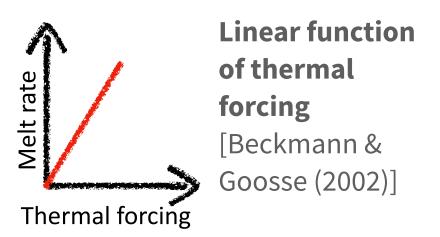
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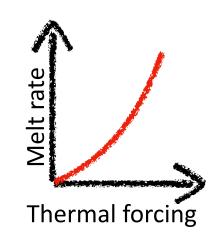
Possible temporal mismatch between the two

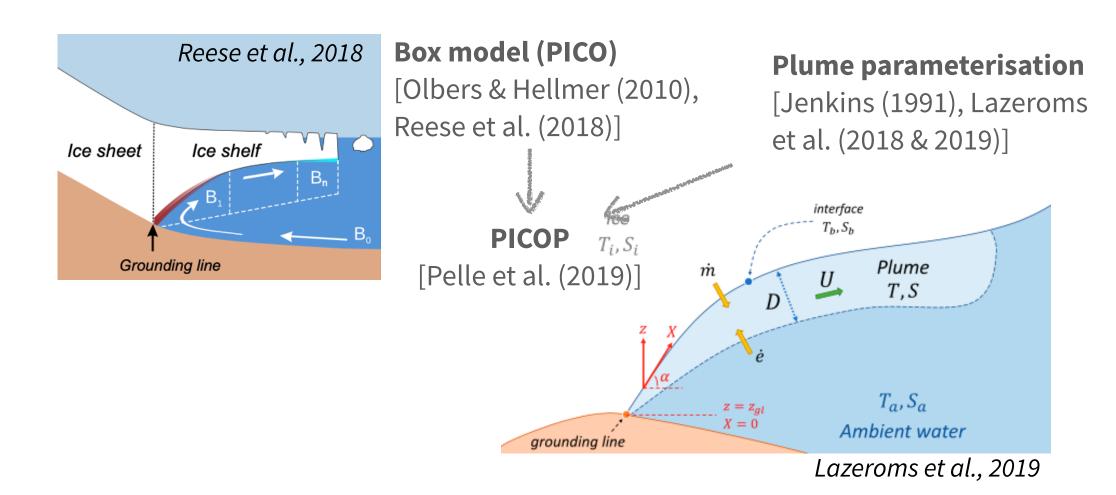


#### The evaluation of these parameterisations is challenging...



Quadratic function of thermal forcing [Holland et al. (2008), De Conto & Pollard (2016), Favier et al. (2019)]





#### **Evaluation with observations**



In-situ observations of input oceanic properties are sparse Satellite estimates of melt rates are uncertain



Possible temporal mismatch between the two

Evaluation with models is one solution.

Assessment in idealised coupled ocean-ice-sheet model simulation was done [Favier et al., 2019].



Only one (idealised) ice shelf

When applied to several Antarctic ice shelves, empirical corrections were needed to get the right present-day melt rates underneath individual sectors or ice shelves [De Conto and Pollard 2016, Lazeroms et al., 2018, Jourdain et al., 2020]



Our goal: Assess and re-tune the existing basal melt parameterisations for circum-Antarctic applications

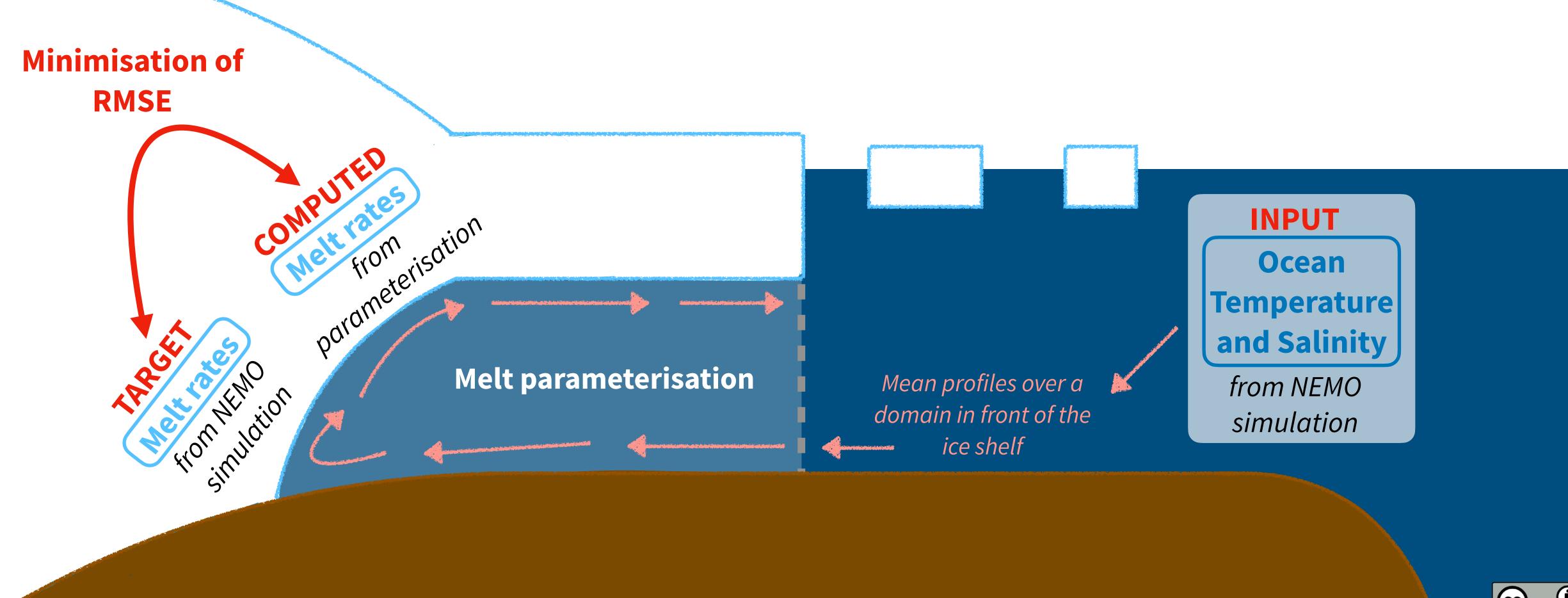


# Our goal: Assess and re-tune the existing basal melt parameterisations for circum-Antarctic applications

#### "Perfect model" approach

Circum-Antarctic ocean simulations (resolving cavities) // virtual reality

tune the parameters in the parameterisations in self-consistent context





# Our goal: Assess and re-tune the existing basal melt parameterisations for circum-Antarctic applications

#### "Perfect model" approach

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Minimisation of RMSE

**Simulations:** 4 x NEMO global ocean simulations conducted by P. Mathiot (for H2020 TiPACCs), on eORCA0.25 grid for in total 127 simulation years.

NEMO resolves the 36 largest cavities and the melt at the ice-ocean interface

Complete From Parameterisation

Melt parameterisation

Mean profiles over a domain in front of the ice shelf

**INPUT** 

Ocean
Temperature
and Salinity

from NEMO simulation

## ariations of simple functions of thermal forcing

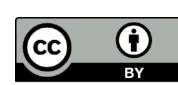
Variations of simple function	om V	$\gamma_{TS,  ext{loc, Ant}}$ or $K$
	$\gamma_{TS, \text{loc, Ant of } 12}$	Tuned (offshore)
Parameterisation	Tuned (50 km)	
	$2.5 \times 10^{-6}$	$0.29 \times 10^{-6}$
Linear-local	$11.8 \times 10^{-5}$	$0.24 \times 10^{-5}$
Quadratic-local Ant slope	$6.6 \times 10^{-5}$	$0.72 \times 10^{-5}$
Quadratic-local cavity slope	1	$0.37 \times 10^{-5}$
Quadratic-local local slope  Quadratic-local local slope	$9.0 \times 10^{-5}$	$0.25 \times 10^{-5}$
Quadratic-local food	$13.0 \times 10^{-5}$	$0.71 \times 10^{-5}$
Quadratic-semilocal Ant slope  Quadratic-semilocal Ant slope	$6.3 \times 10^{-5}$	
Quadratic-semilocal cavity slope	22.10-5	$0.38 \times 10^{-5}$
Quadratic-semilocal local slope	7.37.2	

Parameterisation				
$\begin{array}{c c} L_{azeroms\ formulation} & C_d^{1/2}I \\ L_{azeron} \\ \hline Modified\ version} & 5.9 \times 10^{-3} \\ \hline \end{array}$	$L_{azerom}$ $C_d^{1/2}$	Variations	Of the	
5.9×10-4	$ \begin{array}{c c} 3.6 \times 10^{-2} & 2.1 \times 10^{-4} \\ \hline 1.3 \times 10^{-4} & 3.6 \times 10^{-4} \end{array} $	$\frac{E_0}{tuned (50 \text{ km})}$ $5.4 \times 10^{-2}$	$C_d^{1/2}\Gamma_{TS}$ tuned (offshore)	arameterisation
		1.2×10-2	$10.4 \times 10^{-4}$	$\frac{E_0}{tuned (offshore)}$ $0.39 \times 10^{-3}$

Maximum number of boxes  2 boxes  5 boxes  10 boxes  PICO boxes  Variations of the boxes	original $2 \times 10^{-5}$ $2 \times 10^{-5}$ $2 \times 10^{-5}$ $2 \times 10^{-5}$	$C$ original $1 \times 10^6$ erisation	$0.40 \times 10^{-5}$ $0.43 \times 10^{-5}$ $0.47 \times 10^{-5}$	$C$ tuned (50 km) $12.1 \times 10^{6}$ $12.9 \times 10^{6}$ $14.4 \times 10^{6}$ $15.1 \times 10^{6}$	$\gamma_T^{\star}$ tuned (offshore) $0.56\times10^{-5}$ $0.82\times10^{-5}$ $1.02\times10^{-5}$ $0.70\times10^{-5}$	$C$ tuned (offshore) $0.13 \times 10^{6}$ $0.12 \times 10^{6}$ $0.13 \times 10^{6}$ $0.13 \times 10^{6}$ $0.12 \times 10^{6}$
------------------------------------------------------------------------------------------	--------------------------------------------------------------------------------------	--------------------------------------------------------------------------------------------------------	-------------------------------------------------------------------	-------------------------------------------------------------------------------------------------------	---------------------------------------------------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------------------------------------

Variations of the PICOP parameterisation tuned (offshore)

×10 <sup>-5</sup>	$0.13 \times 10^6$			$-1/2\Gamma \pi S$	E <sub>0</sub>	and (offshore)	tuned (01312) $5.6 \times 10^{-2}$	
PICOP setu		Lazeroms	$\frac{\text{Lazeroms}}{3.6 \times 10^{-2}}$	1.3×10 <sup>-4</sup>	$\frac{\text{tuned } (50 \text{ km})}{3.6 \times 10^{-2}}$	$2.3 \times 10^{-4}$	$9\times10^{-2}$	
PICO bo	XC3						(C)	$\overline{0}$



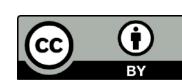
### riations of simple functions of thermal forcing

Variations of simple function	or K	$\gamma_{TS,  ext{loc, Ant}}$ or $K$
Parameterisation	$\gamma_{TS, \text{loc, Ant}}$ or $K$ Tuned (50 km)	Tuned (offshore)
	$2.5 \times 10^{-6}$	$0.29 \times 10^{-6}$
Linear-local	$11.8 \times 10^{-5}$	$0.24 \times 10^{-5}$
Quadratic-local Ant slope	$6.6 \times 10^{-5}$	$0.72 \times 10^{-5}$
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Quadratic-semilocal local slope		

Parameterisation
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
$3.6\times10^{-2}$ $3.6\times10^{-2}$ $2.1\times10^{-4}$ $tuned (50 km)$ $C_s^{1/2}$ $C_s^{1/2}$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$

Variations of the PICOP parameterisation tuned (offshore)

×10 <sup>-5</sup>	$0.12 \times 10^6$			$C_d^{1/2}\Gamma_{ m TS}$	E <sub>0</sub>	and (offshore)	$5.6 \times 10^{-2}$	
PICOP setu		Lazeroms	$3.6 \times 10^{-2}$	tuned (50 km) $1.3 \times 10^{-4}$	$2 \times 10^{-2}$	1 1×10 <sup>-4</sup>	$8.9 \times 10^{-2}$	
PICO bo	xes						$\bigcirc$	•



## riations of simple functions of thermal forcing

Variations of simple function	om V	$\gamma_{TS,  ext{loc, Ant}}$ or $K$
	$\gamma_{TS, \text{loc, Ant of } 12}$	Tuned (offshore)
Parameterisation	Tuned (50 km)	
	$2.5 \times 10^{-6}$	$0.29 \times 10^{-6}$
Linear-local	$11.8 \times 10^{-5}$	$0.24 \times 10^{-5}$
Quadratic-local Ant slope	$6.6 \times 10^{-5}$	$0.72 \times 10^{-5}$
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Parameterisation				
$\begin{array}{c c} L_{azeroms\ formulation} & C_d^{1/2}\Gamma_{TZ} \\ \hline Modified\ version & 5.9\times10^{-4} \\ \hline \end{array}$	$E_0$ $L_{azerom}$ $C_d^{1/2}\Gamma$	Variations	of the	
5.9×10-4	$3.6 \times 10^{-2}$ $2.1 \times 10^{-4}$ $1.3 \times 10^{-4}$	$ \begin{array}{c} E_0 \\ tuned (50 \text{ km}) \\ \hline 5.4 \times 10^{-2} \end{array} $	$C_d^{1/2}\Gamma_{TS}$ tuned (offshore)	Parameterisation
		1.2×10-2	$10.4 \times 10^{-4}$	$E_0$ $tuned (offshore)$ $0.39 \times 10^{-2}$

Movi						
Maximum number	$\gamma_T^\star$					
of boxes	/1	C	$\gamma_T^\star$			
2 boxes	original	original	funed (50 :	C	$\gamma_T^\star$	
5 boxes	$2 \times 10^{-5}$	1×10 <sup>6</sup>		tuned (50 km)	1	C
	2×10 <sup>-5</sup>		$0.40 \times 10^{-5}$	12.1×10 <sup>6</sup>	(olishore)	tuned (offshore)
10 boxes	2×10 <sup>-5</sup>	$1\times10^6$	$0.43 \times 10^{-5}$	12.9×10 <sup>6</sup>	$0.56 \times 10^{-5}$	$0.13 \times 10^{6}$
PICO boxes		$1\times10^6$	$0.47 \times 10^{-5}$	1	$0.82 \times 10^{-5}$	
	$2 \times 10^{-5}$	$1\times10^6$		14.4×10 <sup>6</sup>	$1.02 \times 10^{-5}$	$0.12 \times 10^6$
Variations of the bo	X Daramoi		3.71 × 10 °	$15.1 \times 10^6$		$0.13 \times 10^{6}$
	1941411161	erisation			$0.70 \times 10^{-5}$	$0.12 \times 10^{6}$

×10 <sup>-5</sup>	$0.12 \times 10^{6}$			1/27 - 7	Eo	(offshore)	5.6×10 <sup>-2</sup>
PICOP setu	ap	Lazeroms	Lazeroms to $3.6 \times 10^{-2}$	$\frac{1.3 \times 10^{-4}}{1.3 \times 10^{-4}}$	$\frac{\text{tuned } (50 \text{ km})}{3.6 \times 10^{-2}}$	$2.3 \times 10^{-4}$	8.9×10 <sup>-2</sup>
	- 0						



tuned (offshore)

Variations of the PICOP parameterisation

10 boxes

PICO boxes

## Variations of simple functions of thermal forcing

Variations of simple function	or K	$\gamma_{TS,  ext{loc, Ant}}$ or $K$
	$\gamma_{TS, \text{loc, Ant of } 12}$	Tuned (offshore)
Parameterisation	Tuned (50 km)	$0.29 \times 10^{-6}$
	$2.5 \times 10^{-6}$	
Linear-local	$11.8 \times 10^{-5}$	$0.24 \times 10^{-5}$
Quadratic-local Ant slope	$6.6 \times 10^{-5}$	$0.72 \times 10^{-5}$
Quadratic-local cavity slope	$9.0 \times 10^{-5}$	$0.37 \times 10^{-5}$
Quadratic-local local slope	$9.0 \times 10^{-5}$ $13.0 \times 10^{-5}$	$0.25 \times 10^{-5}$
Quadratic-semilocal Ant slope  Quadratic-semilocal Ant slope		$0.71 \times 10^{-5}$
Quadratic-semilocal cavity slope	$6.3 \times 10^{-5}$	$0.38 \times 10^{-5}$
Quadratic-semilocal slope	$9.3 \times 10^{-5}$	0.307.10
Quadratic-semilocal local slope		

Parameterisation
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
$3.6\times10^{-2}$ $3.6\times10^{-2}$ $2.1\times10^{-4}$ $tuned (50 km)$ $C_s^{1/2}$ $C_s^{1/2}$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$

Maximum number		A				
of boxes	T	C	$\gamma_T^\star$			
2 boxes	original	original	funed (50 s	C tuned (70 c	$\gamma_T^\star$	
5 boxes	$2 \times 10^{-5}$	$1 \times 10^{6}$	$0.40\times10^{-5}$	(30 km)	tuned (offshore)	C tuned (e.c. )
10 boxes	$2 \times 10^{-5}$	$1\times10^6$	$0.43 \times 10^{-5}$	12.1×10 <sup>6</sup>	$0.56 \times 10^{-5}$	(olishore)
PICO boxes	$2 \times 10^{-5}$	1×10 <sup>6</sup>	$0.47 \times 10^{-5}$	12.9×10 <sup>6</sup>	$0.82 \times 10^{-5}$	$0.13 \times 10^{6}$
Variations	2×10 <sup>-5</sup>	1×10 <sup>6</sup>		14.4×10 <sup>6</sup>	$1.02 \times 10^{-5}$	$0.12 \times 10^6$
Variations of the bo	x paramet	erisation		15.1×10 <sup>6</sup>	$0.70 \times 10^{-5}$	$0.13 \times 10^{6}$
		3.41011				$0.12 \times 10^{6}$

Variations of the PICOP parameterisation  $E_0$   $C_d^{1/2}\Gamma_{\rm TS}$ 

0 × 10 -3	$0.12 \times 10^{6}$			Eo	tuned (offshore)	5.6×10 <sup>-2</sup>
			$C_d^{1/2}\Gamma_{\mathrm{TS}}$	nined (50 km)	23×10	$8.9 \times 10^{-2}$
	$\sqrt{\alpha^{1/2}}$	E <sub>0</sub>	tuned (50 km)	$3.6 \times 10^{-2}$	$1.4 \times 10^{-4}$	6.7.
	$C_d^{1/2}$	Lazeroms	1 3×10-4	$2.2 \times 10^{-2}$	1.47	
PICOP setup		$\frac{\text{roms}}{10^{-4}} \frac{10^{-2}}{3.6 \times 10^{-2}}$	10-4	L.L.7		
	5.9>	$(10^{-3} \text{ s} \times 10^{-2})$	1.0			

(cc) (i)

## Variations of simple functions of thermal forcing

Variations of simple function	or K	$\gamma_{TS, \mathrm{loc},  \mathrm{Ant}} \ \mathrm{or} \ K$
Parameterisation	$\gamma_{TS, \text{loc, Ant}}$ or $K$ Tuned (50 km)	Tuned (offshore)
	$2.5 \times 10^{-6}$	$0.29 \times 10^{-6}$
Linear-local	$11.8 \times 10^{-5}$	$0.24 \times 10^{-5}$
Quadratic-local Ant slope	$6.6 \times 10^{-5}$	$0.72 \times 10^{-5}$
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Quadratic-semilocal local slope		

Parameterisation				
$L_{azeroms\ formulation}$ $L_{azeroms\ formulation}$ $L_{azeroms\ formulation}$	$E_0$	Variation		
$\begin{array}{c c} 3.9 \times 10^{-4} \\ 5.9 \times 10^{-4} \end{array}$	$\begin{array}{c c} L_{azeroms} & C_d^{1/2} \Gamma_{TS} \\ \hline 6 \times 10^{-2} & tuned (50 \text{ km}) \\ \times 10^{-2} & 2.1 \times 10^{-4} \end{array}$	$E_0$ $tuned (50)$	of the plume	Darameterisation
	1.3×10-4	1.2×10-2	$10.4 \times 10^{-4}$	tuned (offshore)
				$0.39 \times 10^{-2}$

Variations of the PICOP parameterisation tuned (offshore)

×10 <sup>-5</sup>	$0.12 \times 10^6$			$r^{1/2}\Gamma_{TS}$	Eo (m)	and (offshore)	$\text{tuned (on section of tuned (on section of tun$	
PICOP setu		Lazeroms	$\frac{\text{Lazeroms}}{3.6 \times 10^{-2}}$	tuned (50 km) $1.3 \times 10^{-4}$	$2 \times 10^{-2}$	1 1×10 <sup>-4</sup>	8.9×10 <sup>-2</sup>	
PICO bo	Xes						$\bigcirc$	•



### riations of simple functions of thermal forcing

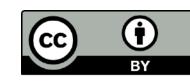
Variations of simple function	or K	$\gamma_{TS, \mathrm{loc, Ant}}$ or $K$
Parameterisation	$\gamma_{TS, \mathrm{loc},  \mathrm{Ant}}$ or 12	Tuned (offshore)
Parameterisation	Tuned (50 km)	$0.29 \times 10^{-6}$
	$2.5 \times 10^{-6}$	$0.29 \times 10^{-5}$ $0.24 \times 10^{-5}$
Linear-local	$11.8 \times 10^{-5}$	
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Quadratic-local local slope	$13.0 \times 10^{-5}$	$0.25 \times 10^{-5}$
Quadratic-semilocal Ant slope	10-5	$0.71 \times 10^{-5}$
Quadratic-semilocal cavity slope		$0.38 \times 10^{-5}$
Quadratic-semilocal local slope	$9.3 \times 10^{-5}$	O.F
Quadratic-sellinocar		

Parameterisation
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
$3.6\times10^{-2}$ $3.6\times10^{-2}$ $2.1\times10^{-4}$ $tuned (50 km)$ $C_s^{1/2}$ $C_s^{1/2}$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$

Maximum number of boxes  2 boxes  5 boxes  10 boxes  PICO boxes  Variations of the box	original $2 \times 10^{-5}$ $2 \times 10^{-5}$ $2 \times 10^{-5}$ $2 \times 10^{-5}$	1×10 <sup>6</sup> 1×10 <sup>6</sup> 1×10 <sup>6</sup>	$0.40 \times 10^{-5}$ $0.43 \times 10^{-5}$ $0.47 \times 10^{-5}$	$C$ tuned (50 km) $12.1 \times 10^{6}$ $12.9 \times 10^{6}$ $14.4 \times 10^{6}$ $15.1 \times 10^{6}$	$\gamma_T^{\star}$ tuned (offshore) $0.56\times10^{-5}$ $0.82\times10^{-5}$ $1.02\times10^{-5}$ $0.70\times10^{-5}$	$C$ tuned (offshore) $0.13 \times 10^{6}$ $0.12 \times 10^{6}$ $0.13 \times 10^{6}$ $0.12 \times 10^{6}$ $0.12 \times 10^{6}$
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Variations of the PICOP parameterisation tuned (offshore)

×10 <sup>-5</sup>	$0.12 \times 10^6$			$C_d^{1/2}\Gamma_{ ext{TS}}$	E <sub>0</sub>	and (offshore)	$5.6 \times 10^{-2}$	
PICOP set		Lazeroms	$\frac{\text{Lazeroms}}{3.6 \times 10^{-2}}$	tuned (50 km) $1.3 \times 10^{-4}$	$2 \times 10^{-2}$	1 1×10 <sup>-4</sup>	8.9×10 <sup>-2</sup>	
PICO bo	oxes						CCC	<b>(i)</b>



### riations of simple functions of thermal forcing

Variations of simple function	or K	$\gamma_{TS,  ext{loc, Ant}}$ or $K$
Parameterisation	$\gamma_{TS, \text{loc, Ant of } 12}$	Tuned (offshore)
Parameterisation	Tuned (50 km)	$0.29 \times 10^{-6}$
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Quadratic-semilocal Ant slope  Quadratic-semilocal Ant slope	1	$0.71 \times 10^{-5}$
Quadratic-semilocal cavity slope	$6.3 \times 10^{-5}$	$0.38 \times 10^{-5}$
Quadratic-semilocal slope	$9.3 \times 10^{-5}$	0.307.23
Quadratic-semilocal local slope		

Parameterisation					
Lazeroms formulation  Modified version	$3.9 \times 10^{-4}$ azerom	$C_d^{1/2}\Gamma_{TS}$	Variations		
	$3.9 \times 10^{-4}$ $3.6 \times 10^{-2}$	$\frac{tuned (50 \text{ km})}{2.1 \times 10^{-4}}$ $1.3 \times 10^{-4}$	$E_0$ $tuned (50 km)$ $5 4$	or the plume p $C_d^{1/2}\Gamma_{TS}$	Parameterisation
		~10-4	$\sqrt{.2}\times10^{-2}$	$10.4 \times 10^{-4}$	$E_0$ $tuned (offshore)$ $0.39 \times 10^{-10}$

Maximum number of boxes  2 boxes  5 boxes  10 boxes  PICO boxes  Variations of the box	original $2 \times 10^{-5}$ $2 \times 10^{-5}$ $2 \times 10^{-5}$ $2 \times 10^{-5}$	1×10 <sup>6</sup> 1×10 <sup>6</sup> 1×10 <sup>6</sup>	$0.40 \times 10^{-5}$ $0.43 \times 10^{-5}$ $0.47 \times 10^{-5}$	$C$ tuned (50 km) $12.1 \times 10^{6}$ $12.9 \times 10^{6}$ $14.4 \times 10^{6}$ $15.1 \times 10^{6}$	$\gamma_T^{\star}$ tuned (offshore) $0.56\times10^{-5}$ $0.82\times10^{-5}$ $1.02\times10^{-5}$ $0.70\times10^{-5}$	$C$ tuned (offshore) $0.13 \times 10^{6}$ $0.12 \times 10^{6}$ $0.13 \times 10^{6}$ $0.12 \times 10^{6}$ $0.12 \times 10^{6}$
----------------------------------------------------------------------------------------	--------------------------------------------------------------------------------------	-------------------------------------------------------	-------------------------------------------------------------------	-------------------------------------------------------------------------------------------------------	---------------------------------------------------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------------------------------------

		- 101	Eo (offshore)
	cah	PICOP paran	
varia	tions of the	1/27-0	Eo
Var		$C_d^{1/2}\Gamma_{TS}$	tuned (offshore)
TS	E <sub>0</sub>	tuned (offshore)	$5.6 \times 10^{-2}$

PICOP setup  10 boxes	$C_d^{1/2}\Gamma_{\mathrm{TS}}$ Lazeroms	Lazeroms tuned (50 km $\frac{1.3 \times 10^{-4}}{3.6 \times 10^{-2}}$ $\frac{1.3 \times 10^{-4}}{1.8 \times 10^{-4}}$	$2.2 \times 10^{-2}$	1 4×10 <sup>-4</sup>	$8.9 \times 10^{-2}$	
PICO boxes						<b>(i)</b>



## ariations of simple functions of thermal forcing

Variations of simple function	<i>K</i>	$\gamma_{TS,  ext{loc, Ant}}$ or $K$
Parameterisation	$\gamma_{TS, \text{loc, Ant of } 12}$	Tuned (offshore)
Parameter	Tuned (50 km) $2.5 \times 10^{-6}$	$0.29 \times 10^{-6}$
Linear-local	$2.5 \times 10^{-5}$ $11.8 \times 10^{-5}$	$0.24 \times 10^{-5}$
Quadratic-local Ant slope	$6.6 \times 10^{-5}$	$0.72 \times 10^{-5}$
Quadratic-local cavity slope	$9.0 \times 10^{-5}$	$0.37 \times 10^{-5}$
Quadratic-local local slope	$13.0 \times 10^{-5}$	$0.25 \times 10^{-5}$
Quadratic-semilocal Ant slope	10-5	$0.71 \times 10^{-5}$
Quadratic-semilocal cavity slope	22.10-5	$0.38 \times 10^{-5}$
Quadratic-semilocal local slope		

Parameterisation  Lazeroms formulation  Modified version	$5.9 \times 10^{-4}$ $3.6 \times 10^{-2}$ $tu$ $3.6 \times 10^{-2}$ $2.$	Variation: $C_d^{1/2}\Gamma_{TS}$ $E_0$ $1 \times 10^{-4}$ $1 \times 10^{-4}$ $1 \times 10^{-4}$ $1 \times 10^{-2}$ $1 \times 10^{-2}$ $1 \times 10^{-2}$ $1 \times 10^{-2}$	$10.4 \times 10^{-4}$ $9.3 \times 10^{2}$	Arameterisation $E_0$ tuned (offshore) $0.39 \times 10^{-2}$ $0.16 \times 10^{-2}$
				0.16×10-2

Maximum number of boxes  2 boxes  5 boxes  10 boxes  PICO boxes	original $2 \times 10^{-5}$ $2 \times 10^{-5}$ $2 \times 10^{-5}$ $2 \times 10^{-5}$	1×10 <sup>6</sup> 1×10 <sup>6</sup> 1×10 <sup>6</sup>	$0.40 \times 10^{-5}$ $0.43 \times 10^{-5}$ $0.47 \times 10^{-5}$	12.1×10 <sup>6</sup> 12.9×10 <sup>6</sup> 14.4×10 <sup>6</sup>	$\gamma_T^{\star}$ tuned (offshore) $0.56 \times 10^{-5}$ $0.82 \times 10^{-5}$ $1.02 \times 10^{-5}$	0.13 $\times$ 10 <sup>6</sup> 0.12 $\times$ 10 <sup>6</sup>
Variations of the box	2×10 <sup>-5</sup> K paramet	1,106		14.4×10 <sup>6</sup> 15.1×10 <sup>6</sup>		$0.12 \times 10^{6}$ $0.13 \times 10^{6}$ $0.12 \times 10^{6}$

Variations of the PICOP parameterisation tuned (offshore) tuned (offshore)  $5.6 \times 10^{-2}$  $E_0$ 

PICOP setup  10 boxes	$C_d^{1/2}\Gamma_{\mathrm{TS}}$ Lazeroms	Lazeroms tuned (50 km) $3.6 \times 10^{-2}$ $1.3 \times 10^{-4}$ $1.8 \times 10^{-4}$	$\frac{\text{tuned } (50 \text{ km})}{3.6 \times 10^{-2}}$	1.4×10 <sup>-4</sup>	8.9×10 <sup>-2</sup>
PICO boxes					



## riations of simple functions of thermal forcing

Variations of simple function	or K	$\gamma_{TS,  ext{loc, Ant}}$ or $K$
Parameterisation	$\gamma_{TS, \mathrm{loc},  \mathrm{Ant}}$ or 12	Tuned (offshore)
Parameterisation	Tuned (50 km)	$0.29 \times 10^{-6}$
	$2.5 \times 10^{-6}$	$0.29 \times 10^{-5}$
Linear-local	$11.8 \times 10^{-5}$	
Quadratic-local Ant slope	$6.6 \times 10^{-5}$	$0.72 \times 10^{-5}$
Quadratic-local cavity slope	$9.0 \times 10^{-5}$	$0.37 \times 10^{-5}$
Quadratic-local local slope	$13.0 \times 10^{-5}$	$0.25 \times 10^{-5}$
Quadratic-semilocal Ant slope  Quadratic-semilocal Ant slope	1	$0.71 \times 10^{-5}$
Quadratic-semilocal cavity slope	$6.3 \times 10^{-5}$	$0.38 \times 10^{-5}$
Quadratic-semilocal local slope	$9.3 \times 10^{-5}$	0.00
Quadratic-semilocar rocar		

Parameterisation				
Modified version 5.9	$C_d^{1/2}\Gamma_{TS}$ $E_0$	Variations of the	he n	
	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$E_0$ $tuned (50 \text{ km})$ $tuned 5.4 \times 10^{-2}$ $tuned (50 \text{ km})$	The plume parameterisation $C_d^{1/2}\Gamma_{TS}$ and $C_d^{1/2}\Gamma_{TS}$	n
		$\frac{1.2\times10^{-2}}{10.2}$	$E_0$ $A \times 10^{-4}$ $E_0$ $A \times 10^{-4}$ $E_0$ $A \times 10^{-4}$	

$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	10 boxes PICO boxes	original $2 \times 10^{-5}$ $2 \times 10^{-5}$ $2 \times 10^{-5}$ $2 \times 10^{-5}$	1×10 <sup>6</sup> 1×10 <sup>6</sup>	$0.40 \times 10^{-5}$ $0.43 \times 10^{-5}$ $0.47 \times 10^{-5}$	12.1×10 <sup>6</sup> 12.9×10 <sup>6</sup> 14.4×10 <sup>6</sup>	0.56 $\times$ 10 <sup>-5</sup> 0.82 $\times$ 10 <sup>-5</sup> 1.02 $\times$ 10 <sup>-5</sup>	0.13 $\times$ 10 <sup>6</sup> 0.12 $\times$ 10 <sup>6</sup> 0.13 $\times$ 10 <sup>6</sup>
-------------------------------------------------------	---------------------	--------------------------------------------------------------------------------------	-------------------------------------	-------------------------------------------------------------------	----------------------------------------------------------------	----------------------------------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------

mate	risation
Variations of the PICOP paramete	
ictions of the Fig.	Eo
Variation $G^{1/2}\Gamma_{TS}$	1 (offsho)

0.12×10	)6	$C_d^{1/2}\Gamma$	tuned (50	$\frac{\text{km})  \text{tuned (61132)}}{2.3 \times 10^{-4}}$	$5.6 \times 10^{-2}$ $8.9 \times 10^{-2}$
	$C_d^{1/2}\Gamma_{ ext{TS}}$	Lazeroms tuned (5	$0 \text{ km}$ $3.6 \times 10$	$1.1 \times 10^{-4}$	8.9×10
PICOP setup	$\frac{\text{Lazeroms}}{5.9 \times 10^{-4}}$	$3.6 \times 10^{-2}$ 1.8×	$10^{-4}$ $2.2 \times 1$	0	
10 boxes	$5.9 \times 10^{-4}$	3.6×10			
PICO boxes					(cc) (i)



### riations of simple functions of thermal forcing

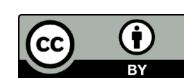
Variations of simple function	or K	$\gamma_{TS,  ext{loc, Ant}}$ or $K$
Parameterisation	$\gamma_{TS, \mathrm{loc},  \mathrm{Ant}}$ or 12	Tuned (offshore)
Parameterisation	Tuned (50 km)	$0.29 \times 10^{-6}$
	$2.5 \times 10^{-6}$	$0.29 \times 10^{-5}$
Linear-local	$11.8 \times 10^{-5}$	
Quadratic-local Ant slope	$6.6 \times 10^{-5}$	$0.72 \times 10^{-5}$
Quadratic-local cavity slope	$9.0 \times 10^{-5}$	$0.37 \times 10^{-5}$
Quadratic-local local slope	$13.0 \times 10^{-5}$	$0.25 \times 10^{-5}$
Quadratic-semilocal Ant slope  Quadratic-semilocal Ant slope	1	$0.71 \times 10^{-5}$
Quadratic-semilocal cavity slope	$6.3 \times 10^{-5}$	$0.38 \times 10^{-5}$
Quadratic-semilocal local slope	$9.3 \times 10^{-5}$	0.00
Quadratic-semilocar rocar		

Parameterisation  Lazeroms formulation  Modified versi	$C_d^{1/2}\Gamma_{TS}$ $L_{azeroms}$ $E_0$			
21310n	$5.9 \times 10^{-4}$ $3.6 \times 10^{-2}$ tur	$C_d^{1/2}\Gamma_{TS}$ led (50 km) $E_0$	s of the plume p	arameterisation
	3~10-2	$\begin{array}{ccc} \lambda & & tuned (50 \text{ km}) \\ \lambda & & 5.4 \times 10^{-2} \\ \lambda & & 7.2 \times 10^{-2} \end{array}$	( June )	Pic.
		7.2×10-2	°-4×10-4	$\frac{tuned\ (offshore)}{0.39\times10^{-2}}$

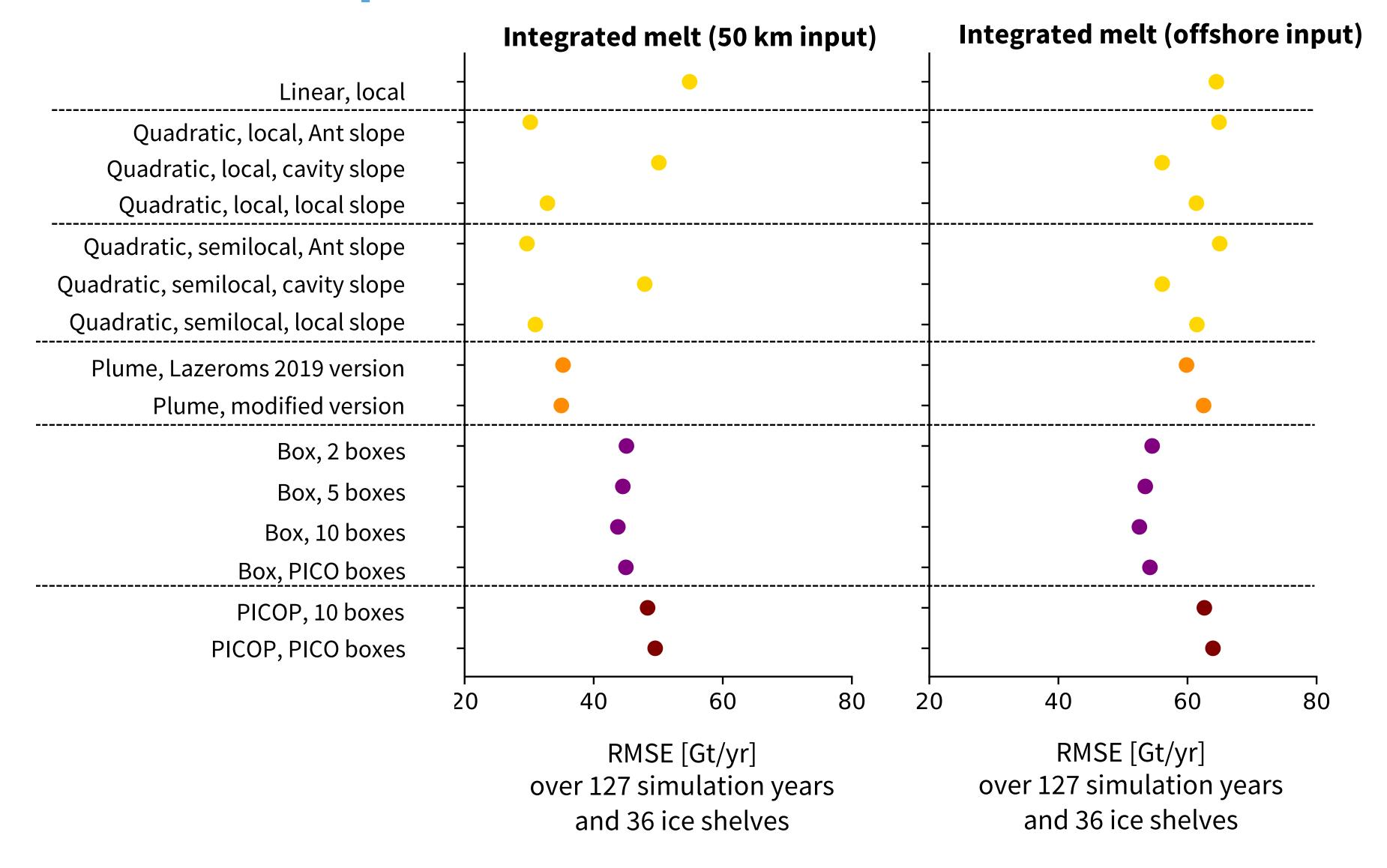
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.56×10 <sup>-5</sup> 0.13×10 <sup>6</sup> 0.82×10 <sup>-5</sup> 0.12×10 <sup>6</sup> 1.02×10 <sup>-5</sup>
-------------------------------------------------------	-------------------------------------------------------------------------------------------------------------------

Variations of the PICOP parameterisation tuned (offshore)

×10-5	0.12×10°					$C_d$	tuned (Onside	
$\times 10^{-5}$	$0.12 \times 10^6$			19 -	Eo	and (offshore)	56×10-2	
			F.	$C_d^{1/2}\Gamma_{\mathrm{TS}}$	tuned (50 km)	2.3×10	89×10 <sup>-2</sup>	_
		$C_d^{1/2}\Gamma_{ ext{TS}}$	Eo	tuned (50 km)	3.6×10 <sup>-2</sup>	1 4×10 <sup>-4</sup>	· ·	
	in		Lazeroms	$1.3 \times 10^{-4}$	$2.2 \times 10^{-2}$			
PICOP setu	AP	1	10/	1.8×10 <sup>-4</sup>				
		$5.9 \times 10^{-4}$	$3.6 \times 10^{-2}$					
10 boxes		5.9×10						

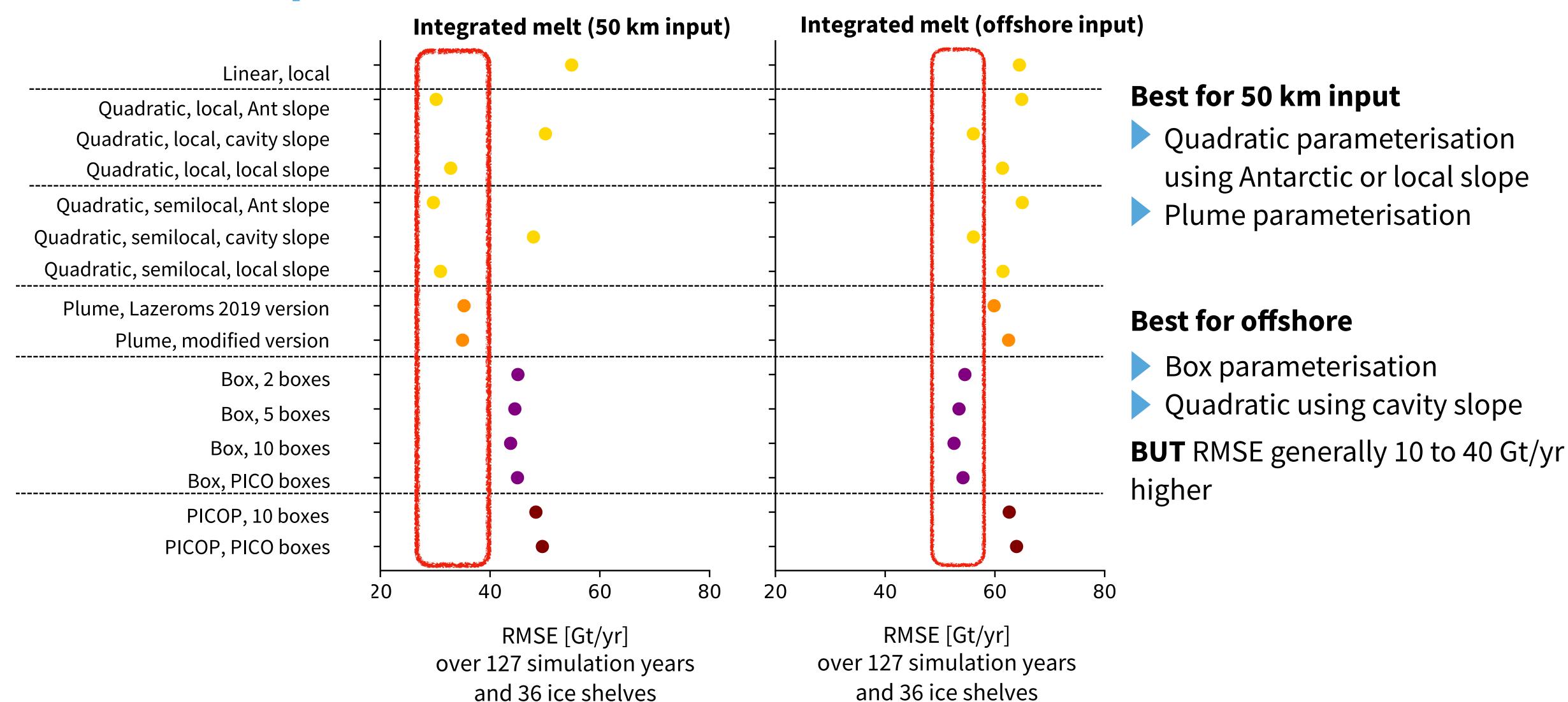


# Using input from the continental shelf leads to a lower RMSE than offshore input





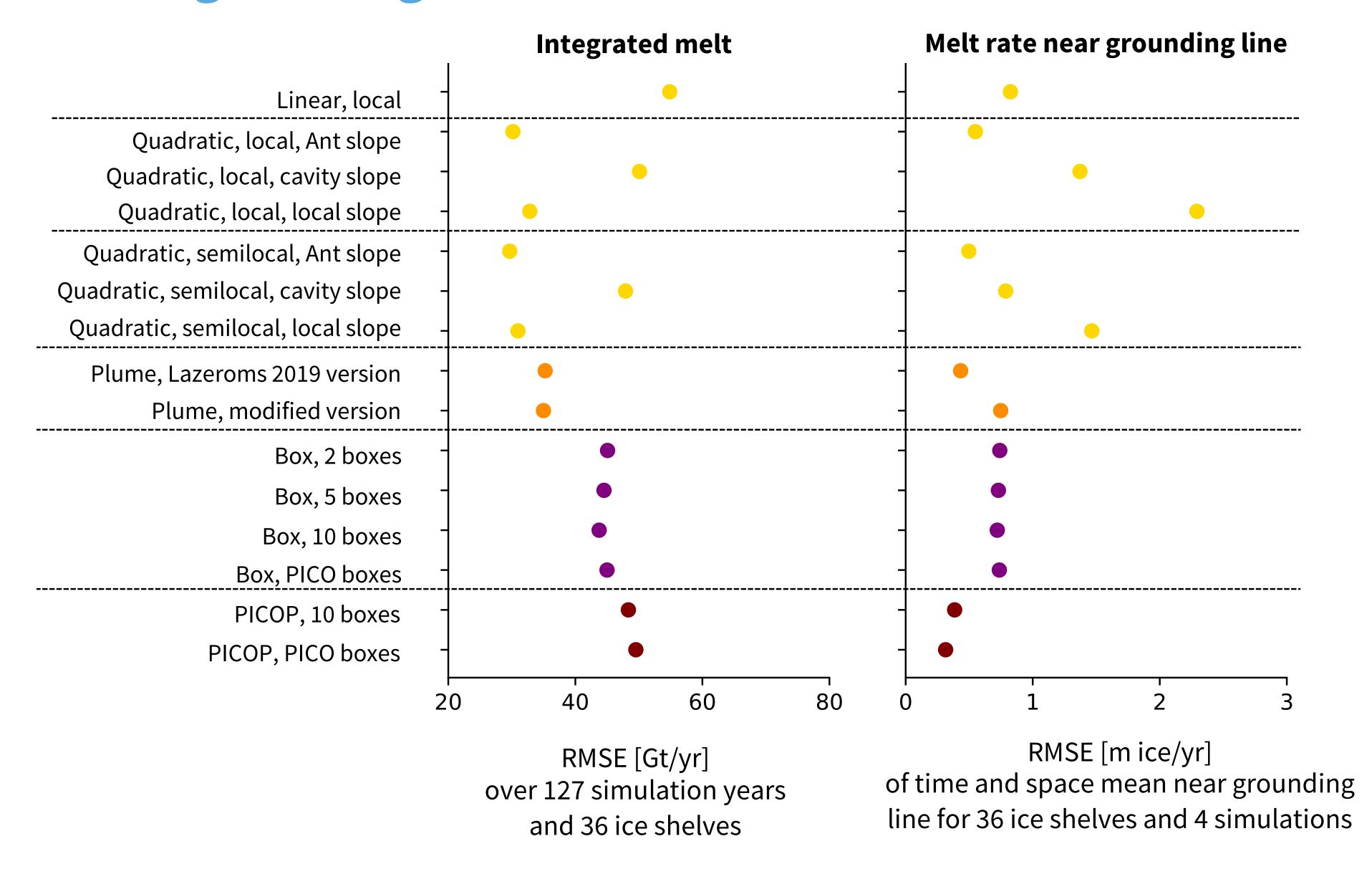
# Using input from the continental shelf leads to a lower RMSE than offshore input



RMSE generally high compared to mean reference integrated ice-shelf melt: 38 Gt/yr

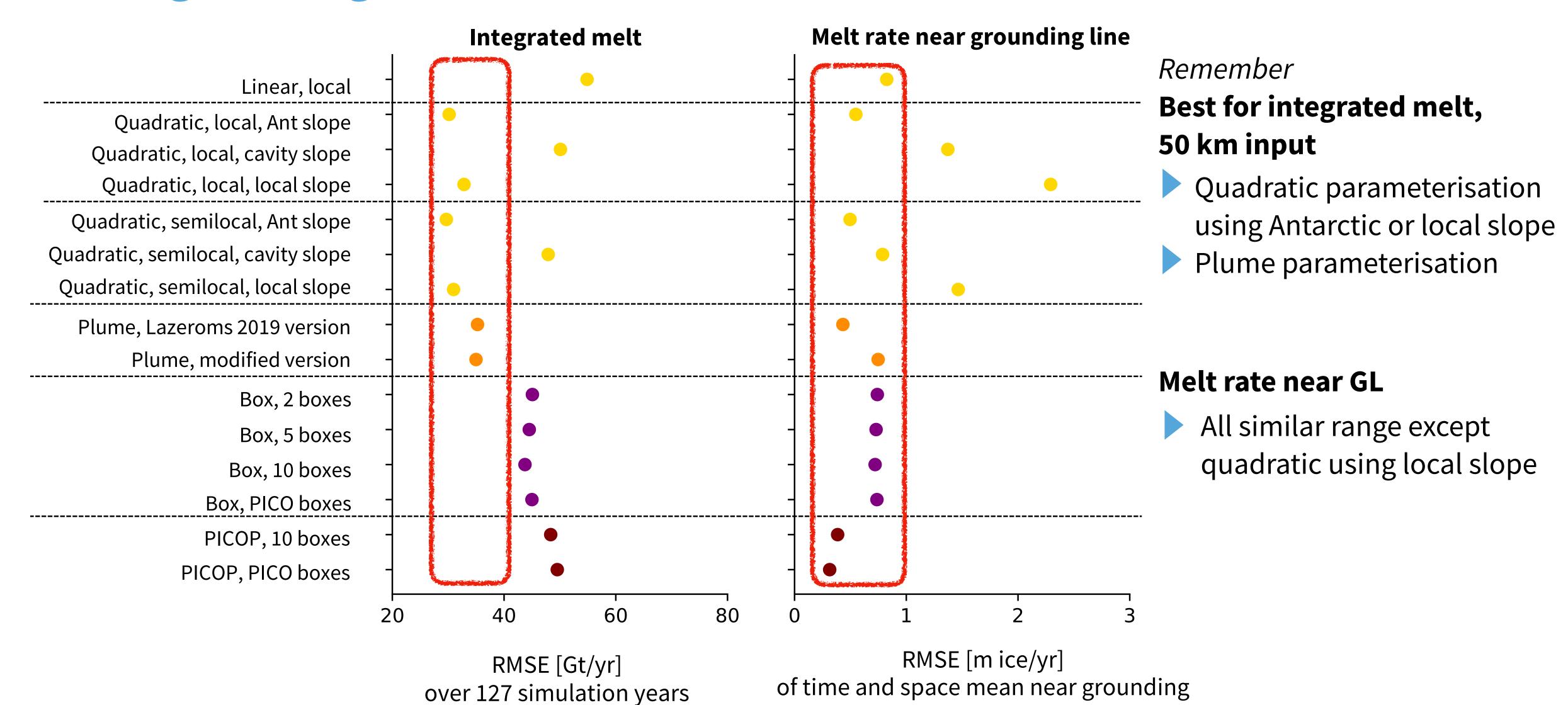


# Not the same parameterisations perform well on ice-shelf level and near grounding line





# Not the same parameterisations perform well on ice-shelf level and near grounding line



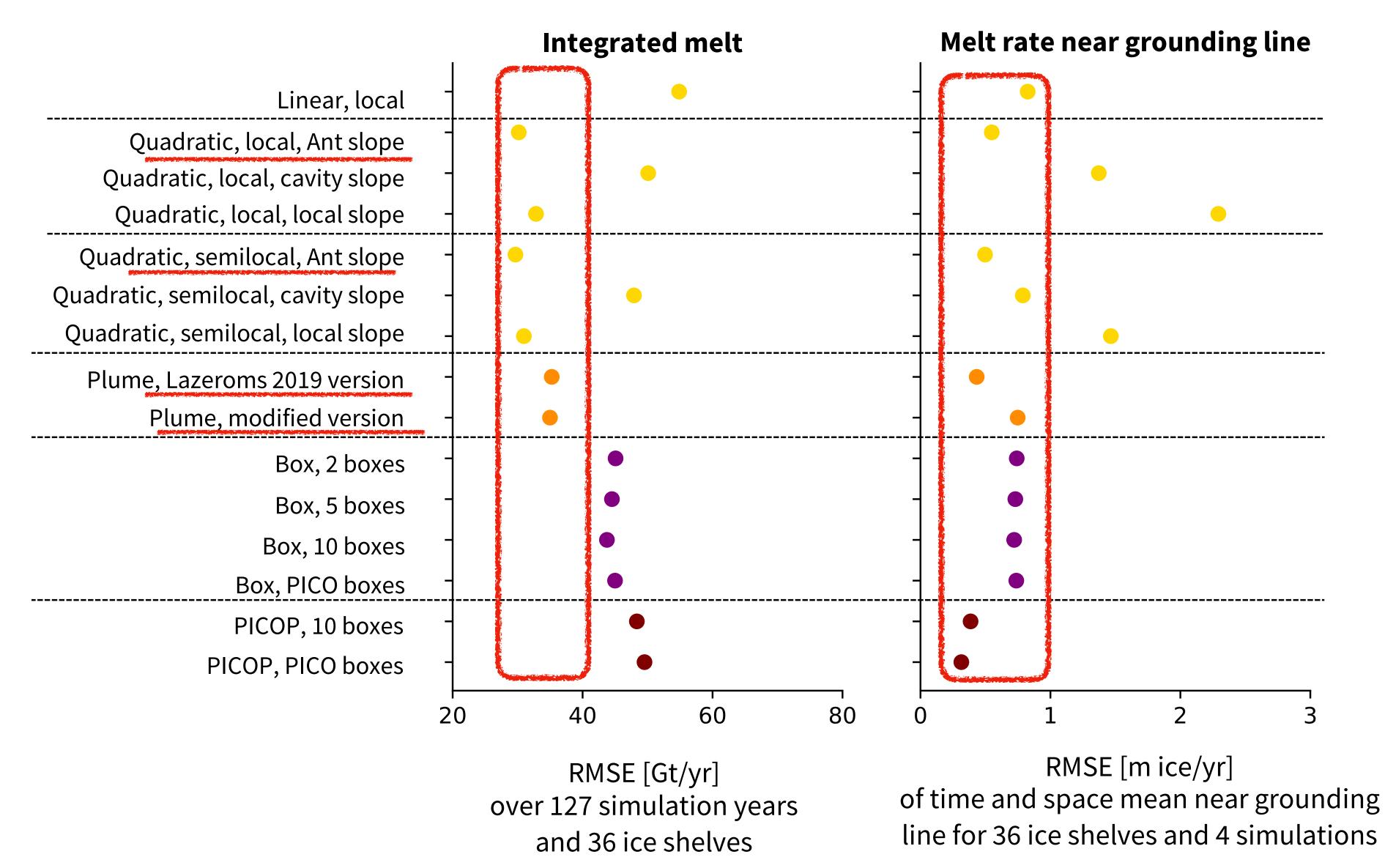
Mean reference melt near the grounding line: 0.44 m ice/yr

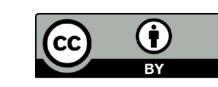
line for 36 ice shelves and 4 simulations



and 36 ice shelves

#### The best compromise...





Mean reference integrated ice-shelf melt: 38 Gt/yr

Mean reference melt near the grounding line: 0.44 m ice/yr

#### More to look forward to in our preprint...

#### Uncertainty distributions for the tuned parameters

Parameterisation							
Plume, Lazeroms $C_d^{1/2}\Gamma_{TS}\times 10^{-4}$ , 500 bootstrap samples) Boxes, PICO boxes ( $\gamma_{TS}^{\star}\times 10^{-5}$ , 200	5th	10th	33rd	Median			
	1.3	1.4	1.7	1.9		90th	95th
	0.21	0.24	0.37	0.45	2.1 0.57	2.7	3.0
PICOP, 10-box setup $(C_d^{1/2}\Gamma_{TS}\times 10^{-4}, 100 \text{ bootstrap samples})$ PICOP, PICO boxes $(C_d^{1/2}\Gamma_{TS}\times 10^{-4}, 100 \text{ bootstrap samples})$	0.24	0.29	0.46	0.59	0.80	1.54	1.96
PICOP, PICO boxes $(C_d^{1/2}\Gamma_{TS}\times 10^{-4}, 100 \text{ bootstrap samples})$	0.96	1.0	1.5	2.7	7.2	1.61 7.8×10 <sup>2</sup>	2.27
T simples)	0.95	1.1	2.1	4.9	_	$9.1 \times 10^4$	$1.7 \times 10^5$
						17.10	$12 \times 10^{4}$

			22 1	Median	66th	90th	95th
	5th	10th	33rd		2.9	6.0	8.0
Parameterisation	2.0	2.0	2.3	2.5	13.1	15.3	15.9
Linear-local ( $\times 10^{-6}$ )	9.5	9.8	11.2	12.1		8.8	9.3
Occidentical Ant slope (×10)	4.1	4.6	5.9	6.6	7.4		10.0
Our dratic-local cavity slope (×10)		7.5	8.5	8.9	9.3	9.8	16.4
local local slope (X10)	7.1	11.1	12.4	13.3	14.2	16.0	
Quadratic-local food Quadratic-semilocal Ant slope ( $\times 10^{-5}$ )	10.7		5.5	6.4	7.2	8.9	9.4
Quadratic-semilocal cavity slope ( $\times 10^{-5}$ )  Quadratic-semilocal cavity slope ( $\times 10^{-5}$ )	3.6	4.1		0.2	9.6	10.2	10.4
Quadratic-semilocal cavity step ( $\times 10^{-5}$ )	7.3	7.8	8.8	7.2			
Quadratic-semilocal local slope (							

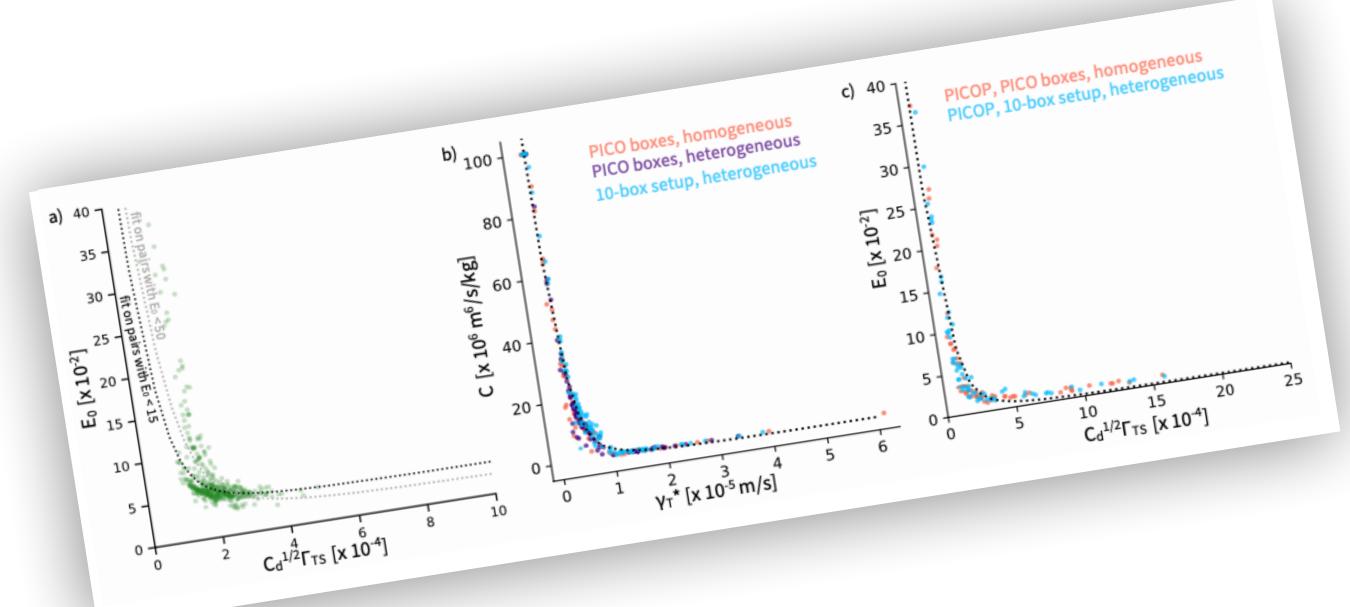


#### More to look forward to in our preprint...

#### Uncertainty distributions for the tuned parameters

Parameterisation							
Plume, Lazeroms $C_d^{1/2}\Gamma_{TS} \times 10^{-4}$ , 500 bootstrap samples) Boxes, PICO boxes ( $\gamma_T^* \times 10^{-5}$ , 200	5th	10th	33rd	Median	66th	00.1	
	1.3	1.4	1.7	1.9	2.1	90th	95th
	0.21	0.24	0.37	0.45	0.57	2.7 1.54	3.0
PICOP, 10-box setup $(C_d^{1/2}\Gamma_{TS}\times 10^{-4}, 100 \text{ bootstrap samples})$ PICOP, PICO boxes $(C_d^{1/2}\Gamma_{TS}\times 10^{-4}, 100 \text{ bootstrap samples})$	0.24 0.96	0.29	0.46	0.59	0.80	1.61	1.96
PICOP, PICO boxes $(C_d^{1/2}\Gamma_{TS}\times 10^{-4}, 100 \text{ bootstrap samples})$	0.96	1.0	1.5	2.7	7.2	$7.8 \times 10^{2}$	2.27
	3.55	1.1	2.1	4.9		9.1×10 <sup>4</sup>	$1.7 \times 10^5$ $12 \times 10^4$

				Median	66th	90th	95th
	5th	10th	33rd		2.9	6.0	8.0
Parameterisation	2.0	2.0	2.3	2.5	13.1	15.3	15.9
Linear-local ( $\times 10^{-6}$ )	9.5	9.8	11.2	12.1		8.8	9.3
o a drotic-local Ant slope (×10)	4.1	4.6	5.9	6.6	7.4		10.0
Overdratic-local cavity slope (×10)		7.5	8.5	8.9	9.3	9.8	
1 testic local local slope (X10)	7.1		12.4	13.3	14.2	16.0	16.4
Quadratic-local Food Ant slope ( $\times 10^{-5}$ )  Quadratic-semilocal Ant slope ( $\times 10^{-5}$ )	10.7	11.1		6.4	7.2	8.9	9.4
Quadratic-sellifocal rapid y slope ( $\times 10^{-5}$ )	3.6	4.1	5.5	9.2	9.6	10.2	10.4
Quadratic-semilocal cavity slope ( $\times 10^{-5}$ )  Quadratic-semilocal cavity slope ( $\times 10^{-5}$ )	7.3	7.8	8.8	9.2			
Quadratic-semilocal local slope ( $\times 10^{-5}$ )							



Empirical relationships between the two tuneable parameters of the complex parameterisations

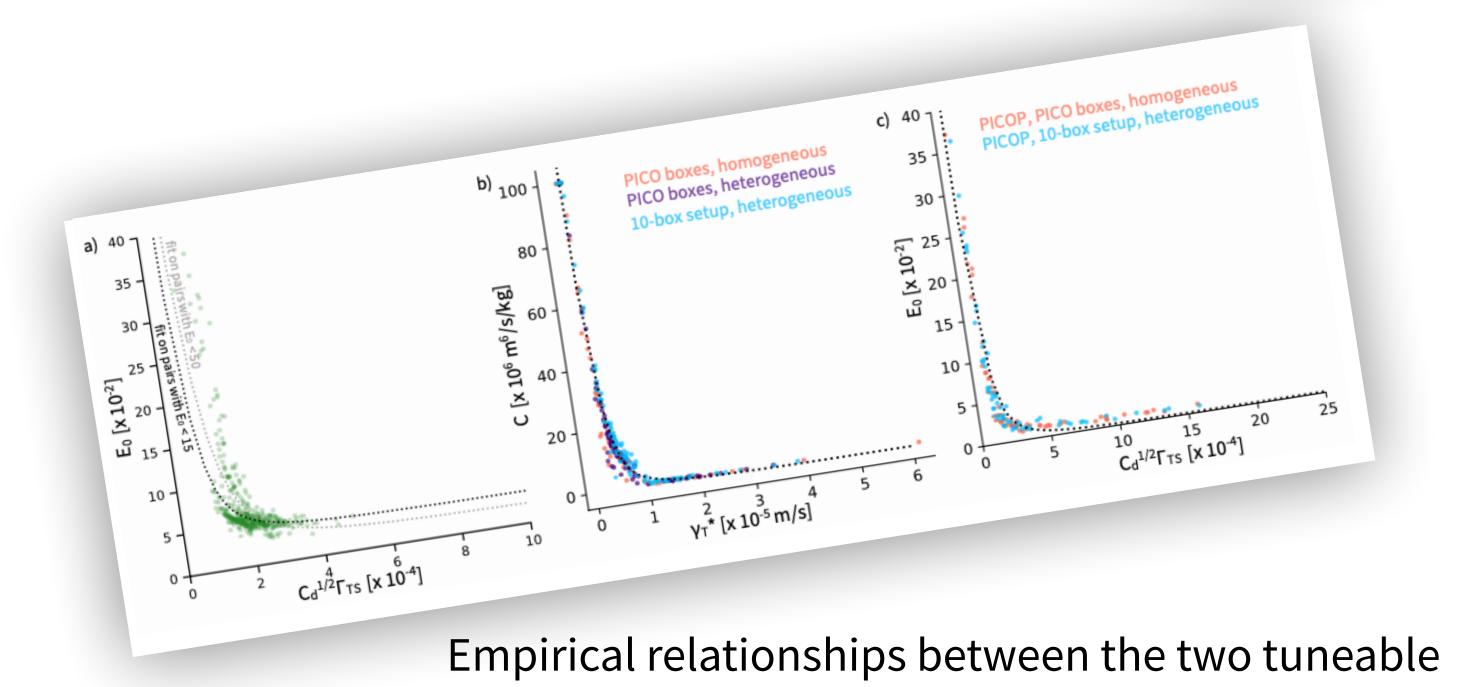


#### More to look forward to in our preprint...

#### Uncertainty distributions for the tuned parameters

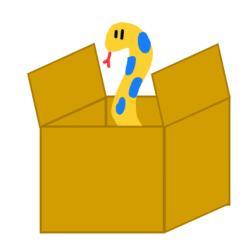
Parameterisation							
Plume, Lazeroms $C_d^{1/2}\Gamma_{TS} \times 10^{-4}$ , 500 bootstrap samples) Boxes, PICO boxes ( $\gamma_{T}^* \times 10^{-5}$ , 200	5th	10th	33rd	Median	66th	001	
	1.3	1.4	1.7	1.9	2.1	90th	95th
	0.21	0.24	0.37	0.45	0.57	2.7	3.0
	0.24	0.29	0.46	0.59	0.80	1.54	1.96
PICOP, PICO boxes $(C_d^{1/2}\Gamma_{TS}\times 10^{-4}, 100 \text{ bootstrap samples})$	0.96	1.0	1.5	2.7	_	1.61 7.8×10 <sup>2</sup>	2.27
r samples)	0.95	1.1	2.1	4.9		$9.1 \times 10^{4}$	$1.7 \times 10^{5}$
						J.1 × 10	$12 \times 10^{4}$

				Median	66th	90th	95tn
	5th	10th	33rd		2.9	6.0	8.0
Parameterisation	2.0	2.0	2.3	2.5			15.9
Linear-local ( $\times 10^{-6}$ )		9.8	11.2	12.1	13.1	15.3	
Quadratic-local Ant slope ( $\times 10^{-5}$ )	9.5		5.9	6.6	7.4	8.8	9.3
Quadratic-local Ante series ( $\times 10^{-5}$ )	4.1	4.6		8.9	9.3	9.8	10.0
Quadratic-local cavity slope ( $\times 10^{-5}$ )  Quadratic-local cavity slope ( $\times 10^{-5}$ )	7.1	7.5	8.5		14.2	16.0	16.4
1 astic local local slope (X10)	10.7	11.1	12.4	13.3			9.4
1 stic semilocal Ant slope (^10)		4.1	5.5	6.4	7.2	8.9	
Quadratic-semilocal cavity slope ( $\times 10^{-5}$ )  Quadratic-semilocal cavity slope ( $\times 10^{-5}$ )	3.6			9.2	9.6	10.2	10.4
Quadratic-semilocal cavity $(\times 10^{-5})$	7.3	7.8	8.8				
Quadratic-semilocal local slope ( $\times 10^{-5}$ )							



parameters of the complex parameterisations

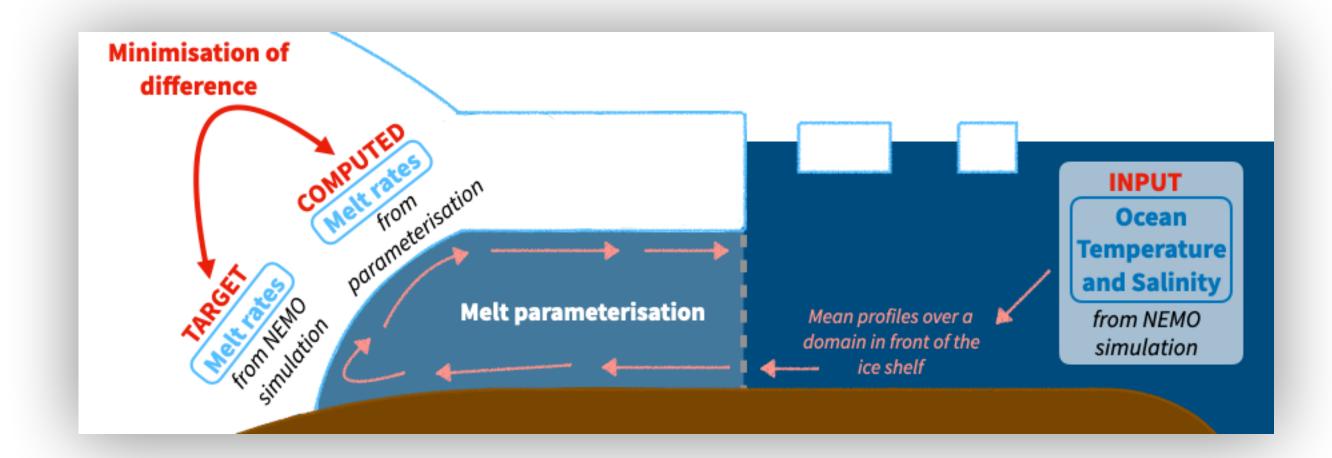
# And ... check out our python package!



https://github.com/ ClimateClara/multimelt/



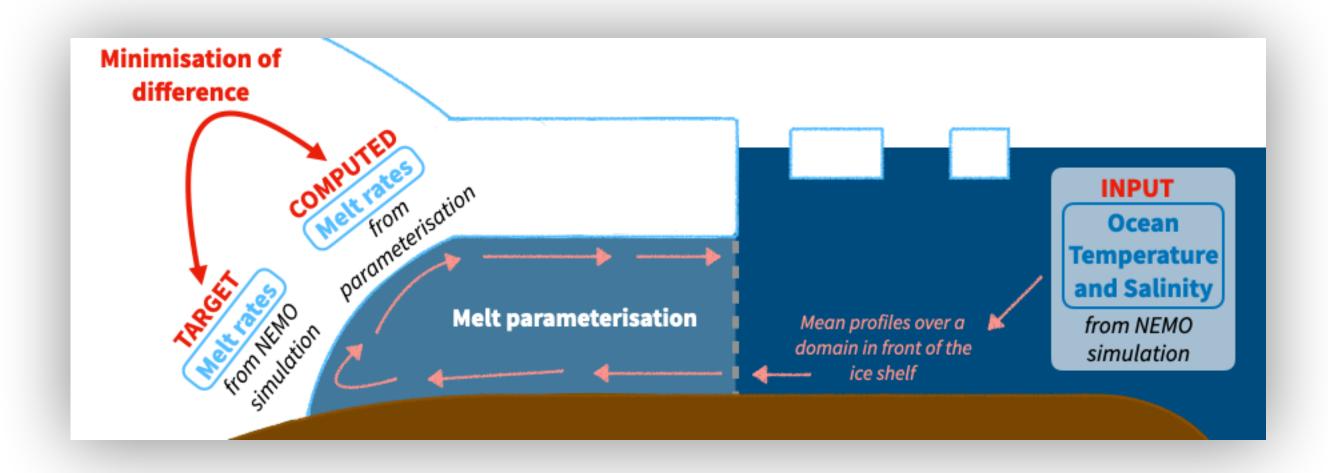
We use a "perfect-model" approach with an ensemble of circum-Antarctic ocean simulations to re-tune existing basal melt parameterisations.

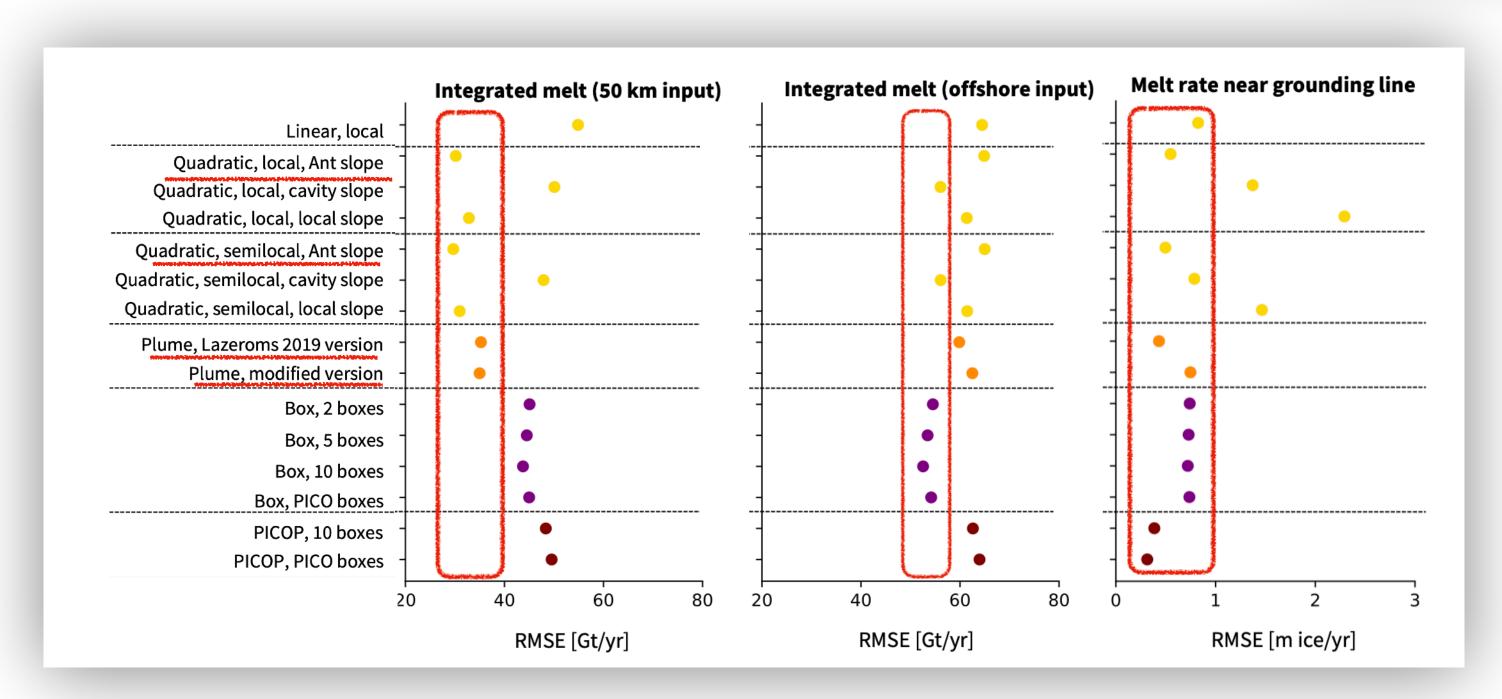






We use a "perfect-model" approach with an ensemble of circum-Antarctic ocean simulations to re-tune existing basal melt parameterisations.



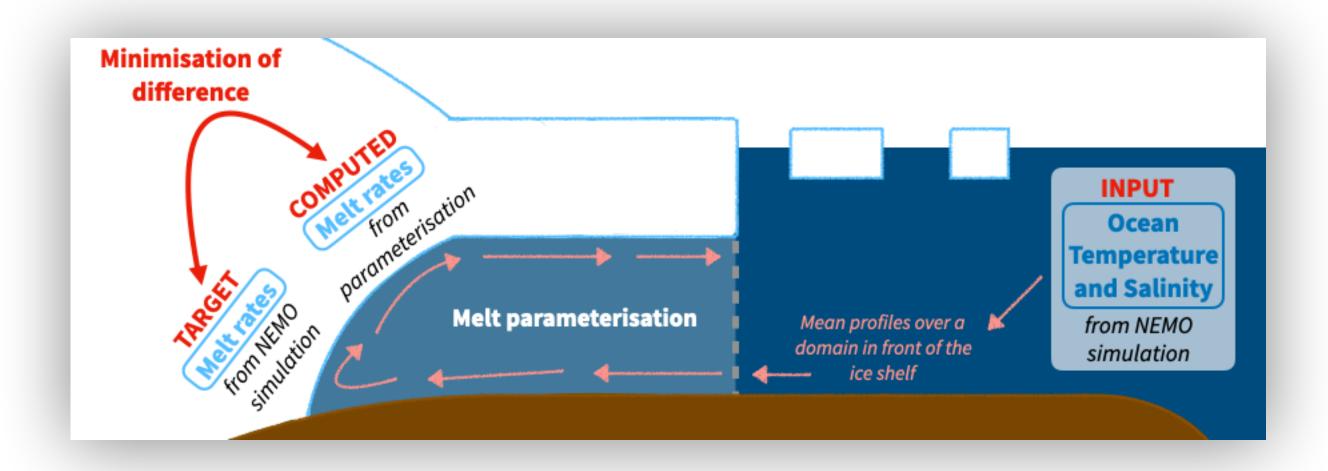


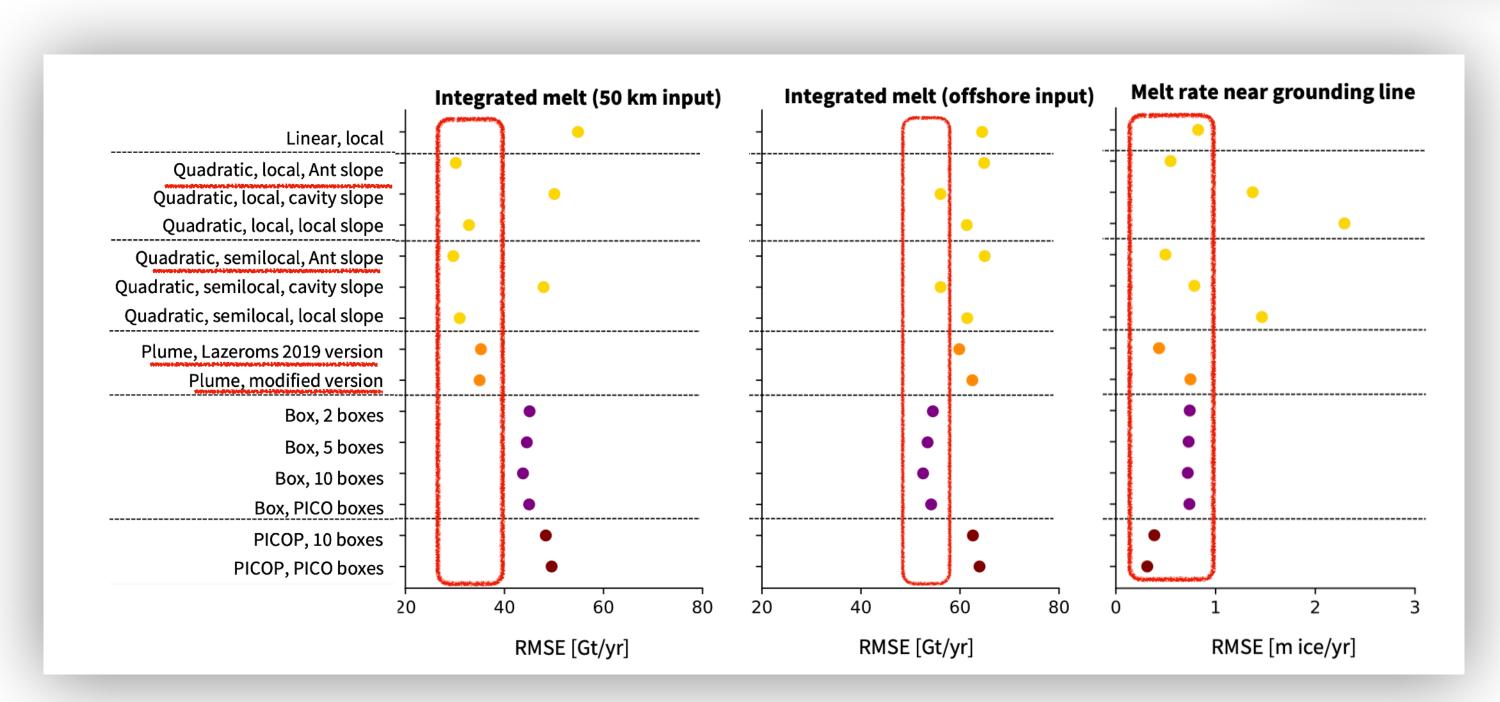
All parameterisations result in **high RMSE compared to the reference** even after re-tuning





We use a "perfect-model" approach with an ensemble of circum-Antarctic ocean simulations to re-tune existing basal melt parameterisations.

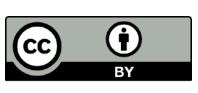




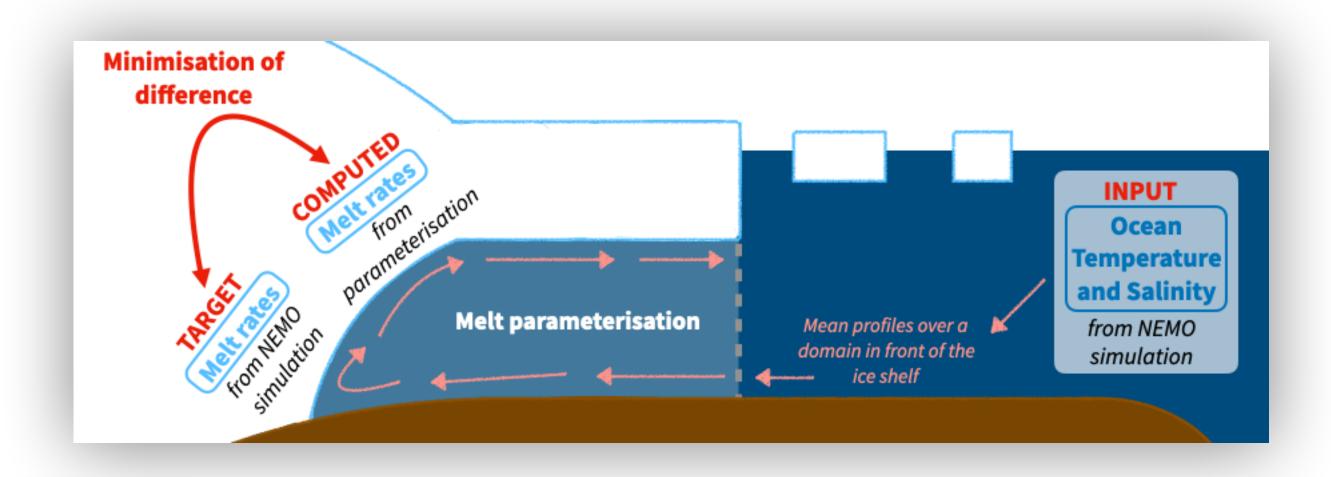
All parameterisations result in **high RMSE compared to the reference** even after re-tuning

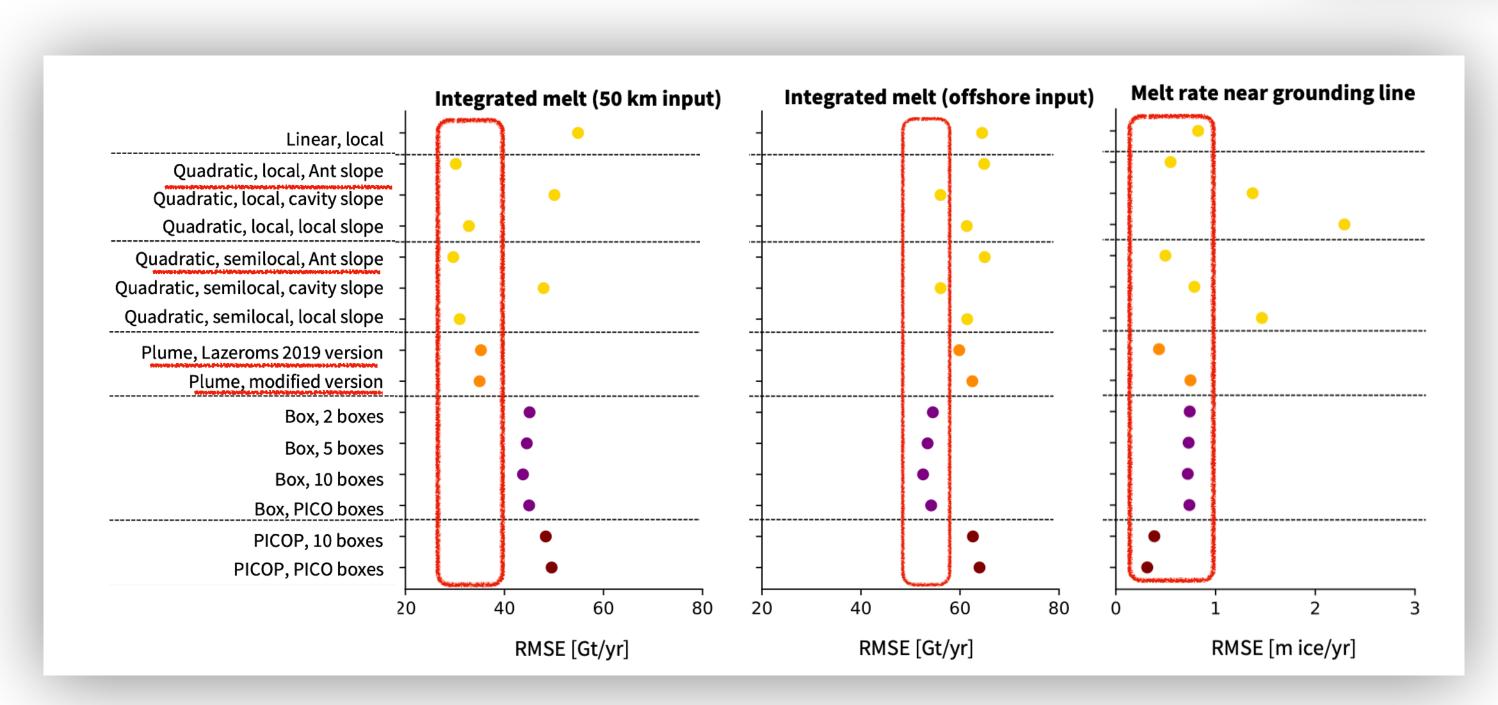
If possible, **prefer input averaged over the continental shelf** to averaged over an offshore region





We use a "perfect-model" approach with an ensemble of circum-Antarctic ocean simulations to re-tune existing basal melt parameterisations.





All parameterisations result in high RMSE compared to the reference even after re-tuning

If possible, prefer input averaged over the continental shelf to averaged over an offshore region

Parameterisations with lowest RMSE on integrated ice-shelf melt and near grounding line are the quadratic formulation using constant Antarctic slope and the plume parameterisation



THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT 869304.

Check out the preprint and comment if you have ideas/suggestions: <a href="https://tc.copernicus.org/">https://tc.copernicus.org/</a>

preprints/tc-2022-32/