An assessment of basal melt parameterisations for Antarctic ice shelves

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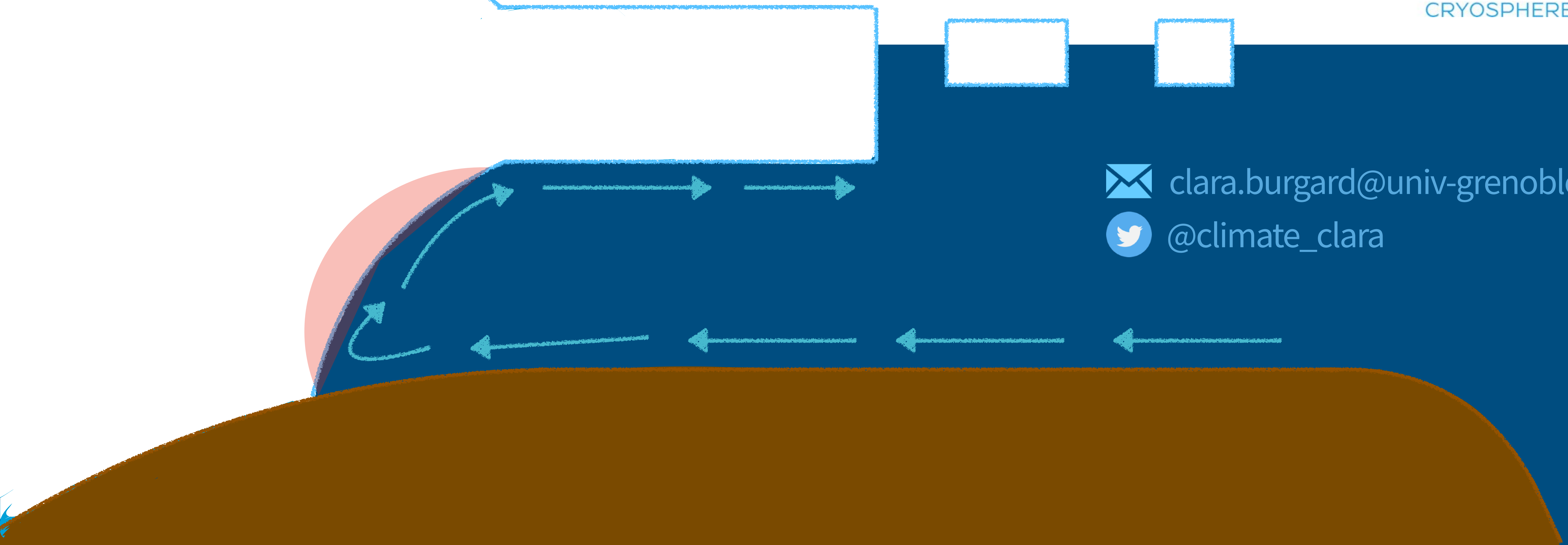
Preprint in *The Cryosphere Discussions*

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

EGU General Assembly 2022

This work is part of Protect CRYOSPHERE & SEA LEVEL



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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…

Sub-shelf cavities are typically not resolved in ocean or coupled-climate models…

The link between the open ocean and the ocean-ice sheet interface is missing!

Basal melt parameterisations exist to bridge the gap

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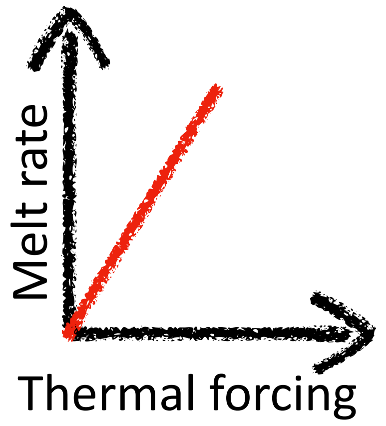

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[Beckmann & Goosse (2002)]

Quadratic function of thermal forcing
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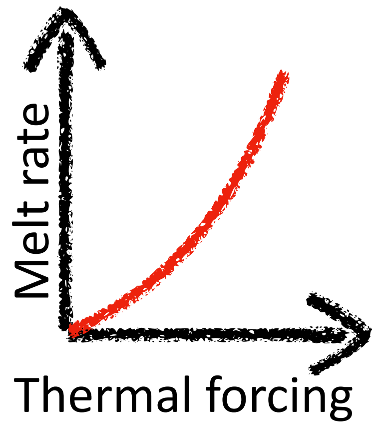

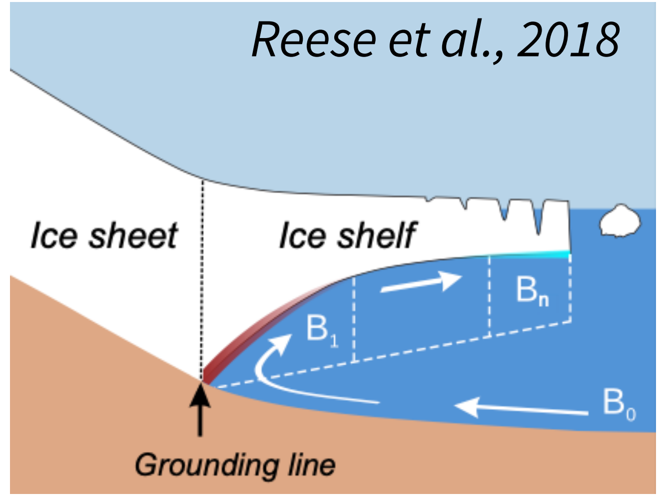

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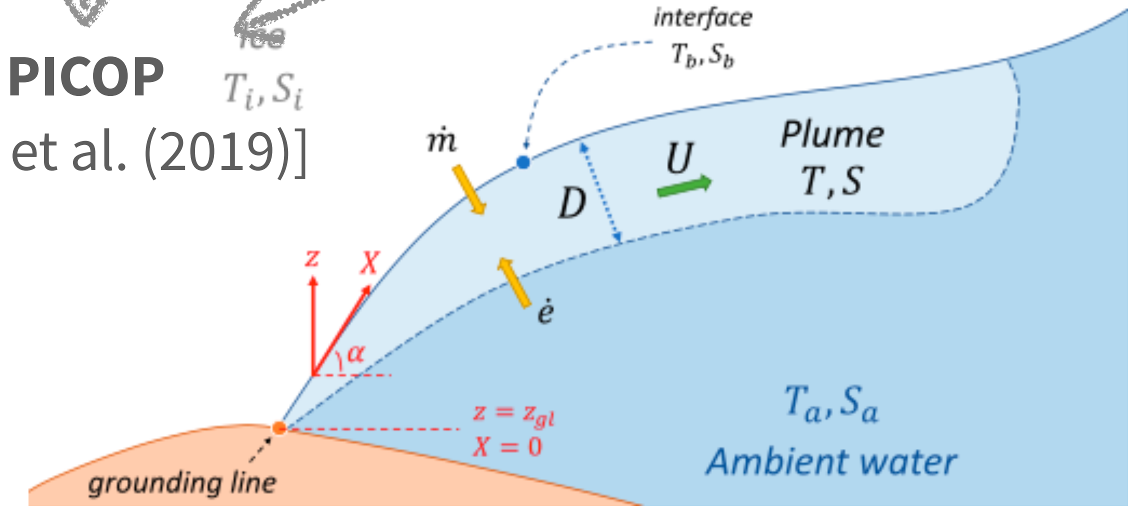

Lazeroms et al., 2019

Evaluation with observations

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

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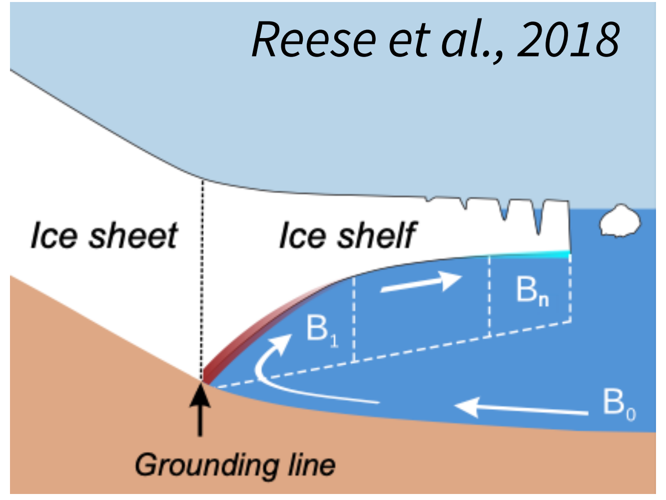

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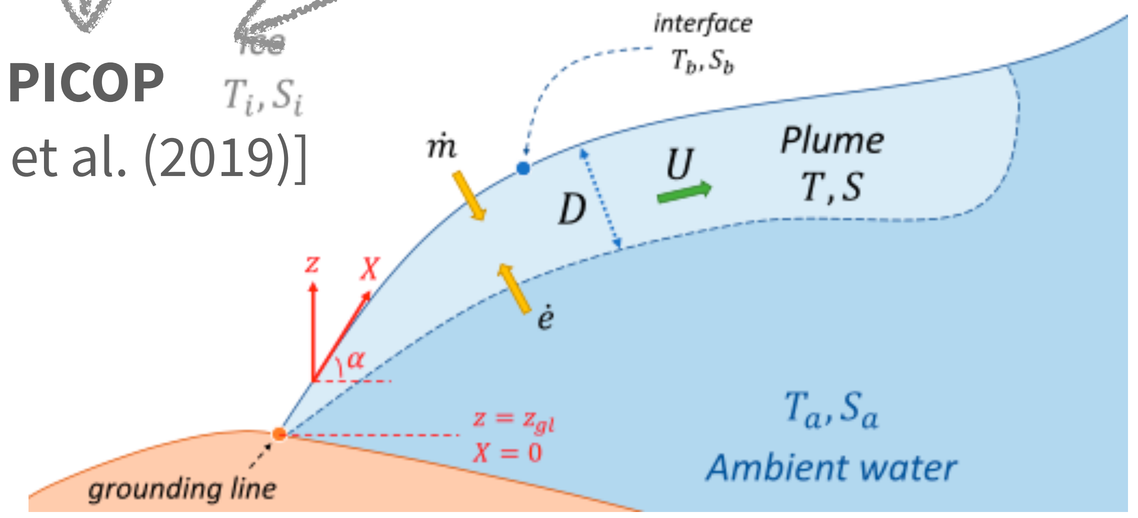

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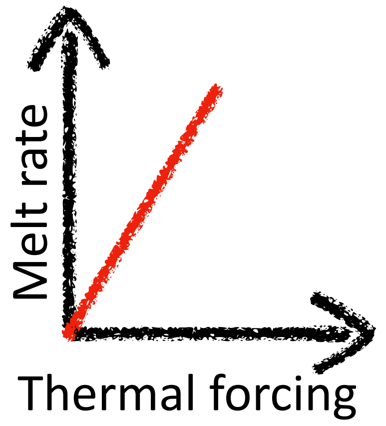

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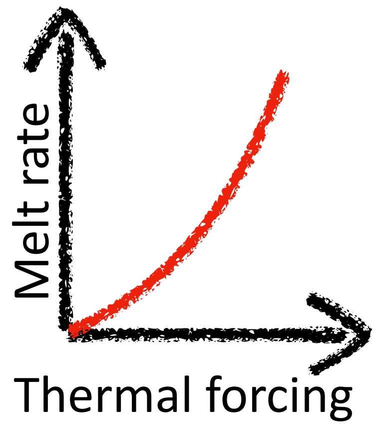

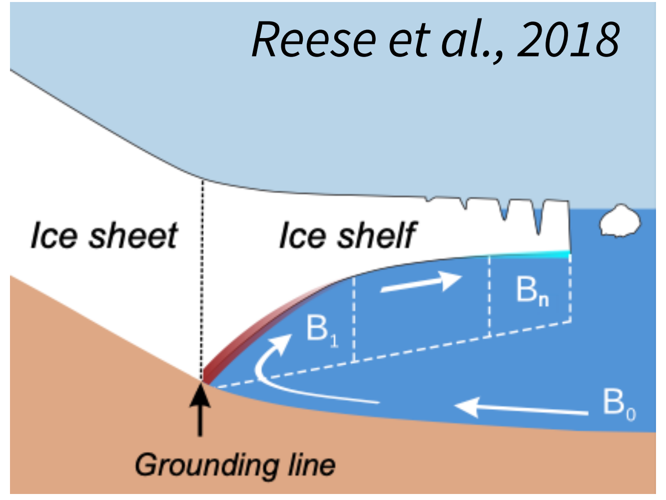

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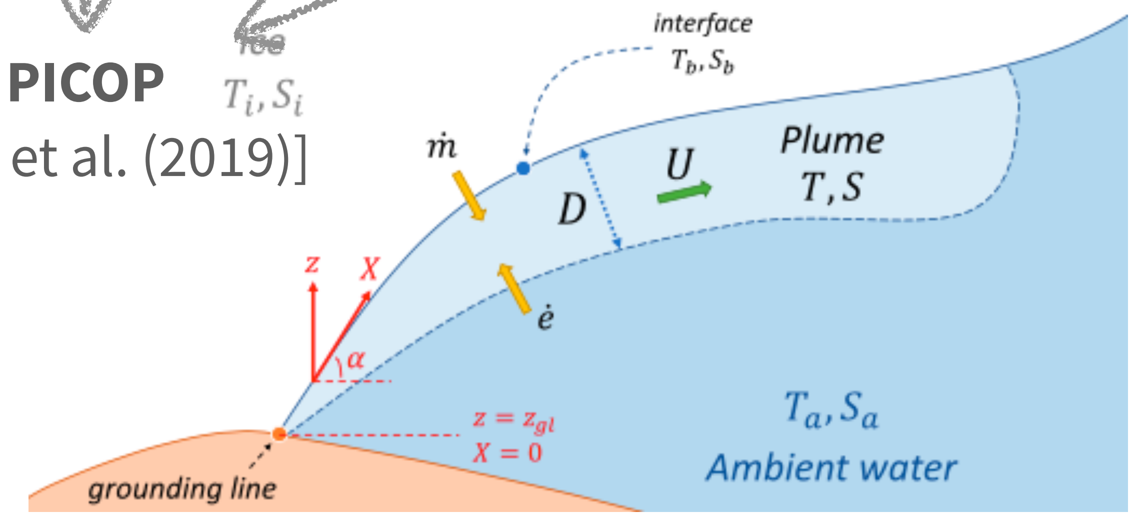

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Evaluation with models is one solution.
Assessment in idealised coupled ocean-ice-sheet model simulation was done [Favier et al., 2019].

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]

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

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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

Re-tuning the parameterisations on the circum-Antarctic scale, a quick look

Variations of simple functions of thermal forcing

Parameterisation	$\gamma_{TS,\text{loc, Ant}}$ or K Tuned (50 km)	$\gamma_{TS,\text{loc, Ant}}$ or K Tuned (offshore)
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Parameterisation	$C_d^{1/2}\Gamma_{TS}$ Lazeroms	E_0 Lazeroms	$C_d^{1/2}\Gamma_{TS}$ tuned (50 km)	E_0 tuned (50 km)	$C_d^{1/2}\Gamma_{TS}$ tuned (offshore)	E_0 tuned (offshore)
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PICO boxes	5.9×10^{-4}	3.6×10^{-2}	1.8×10^{-4}	2.2×10^{-2}	1.4×10^{-4}	8.9×10^{-2}

Re-tuning the parameterisations on the circum-Antarctic scale, a quick look

Variations of simple functions of thermal forcing

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

Variations of the plume parameterisation

Parameterisation	$C_d^{1/2}\Gamma_{TS}$ Lazeroms	E_0 Lazeroms	$C_d^{1/2}\Gamma_{TS}$ tuned (50 km)	E_0 tuned (50 km)	$C_d^{1/2}\Gamma_{TS}$ tuned (offshore)	E_0 tuned (offshore)
Lazeroms formulation	5.9×10^{-4}	3.6×10^{-2}	2.1×10^{-4}	5.4×10^{-2}	10.4×10^{-4}	0.39×10^{-2}
Modified version	5.9×10^{-4}	3.6×10^{-2}	1.3×10^{-4}	7.2×10^{-2}	9.3×10^{2}	0.16×10^{-2}

Variations of the box parameterisation

Maximum number of boxes	$\gamma_T^\star$ original	C original	$\gamma_T^\star$ tuned (50 km)	C tuned (50 km)	$\gamma_T^\star$ tuned (offshore)	C tuned (offshore)
2 boxes	2×10^{-5}	1×10^{6}	0.40×10^{-5}	12.1×10^{6}	0.56×10^{-5}	0.13×10^{6}
5 boxes	2×10^{-5}	1×10^{6}	0.43×10^{-5}	12.9×10^{6}	0.82×10^{-5}	0.12×10^{6}
10 boxes	2×10^{-5}	1×10^{6}	0.47×10^{-5}	14.4×10^{6}	1.02×10^{-5}	0.13×10^{6}
PICO boxes	2×10^{-5}	1×10^{6}	0.41×10^{-5}	15.1×10^{6}	0.70×10^{-5}	0.12×10^{6}

Variations of the PICOP parameterisation

PICOP setup	$C_d^{1/2}\Gamma_{TS}$ Lazeroms	E_0 Lazeroms	$C_d^{1/2}\Gamma_{TS}$ tuned (50 km)	E_0 tuned (50 km)	$C_d^{1/2}\Gamma_{TS}$ tuned (offshore)	E_0 tuned (offshore)
10 boxes	5.9×10^{-4}	3.6×10^{-2}	1.3×10^{-4}	3.6×10^{-2}	2.3×10^{-4}	5.6×10^{-2}
PICO boxes	5.9×10^{-4}	3.6×10^{-2}	1.8×10^{-4}	2.2×10^{-2}	1.4×10^{-4}	8.9×10^{-2}

Re-tuning the parameterisations on the circum-Antarctic scale, a quick look

Variations of simple functions of thermal forcing

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Variations of the plume parameterisation

Parameterisation	$C_d^{1/2}\Gamma_{TS}$ Lazeroms	E_0 Lazeroms	$C_d^{1/2}\Gamma_{TS}$ tuned (50 km)	E_0 tuned (50 km)	$C_d^{1/2}\Gamma_{TS}$ tuned (offshore)	E_0 tuned (offshore)
Lazeroms formulation	5.9×10^{-4}	3.6×10^{-2}	2.1×10^{-4}	5.4×10^{-2}	10.4×10^{-4}	0.39×10^{-2}
Modified version	5.9×10^{-4}	3.6×10^{-2}	1.3×10^{-4}	7.2×10^{-2}	9.3×10^{2}	0.16×10^{-2}

Variations of the box parameterisation

Maximum number of boxes	$\gamma_T^\star$ original	C original	$\gamma_T^\star$ tuned (50 km)	C tuned (50 km)	$\gamma_T^\star$ tuned (offshore)	C tuned (offshore)
2 boxes	2×10^{-5}	1×10^{6}	0.40×10^{-5}	12.1×10^{6}	0.56×10^{-5}	0.13×10^{6}
5 boxes	2×10^{-5}	1×10^{6}	0.43×10^{-5}	12.9×10^{6}	0.82×10^{-5}	0.12×10^{6}
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Variations of the PICOP parameterisation

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10 boxes	5.9×10^{-4}	3.6×10^{-2}	1.3×10^{-4}	3.6×10^{-2}	2.3×10^{-4}	5.6×10^{-2}
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Variations of the plume parameterisation

Parameterisation	$C_d^{1/2}\Gamma_{TS}$ Lazeroms	E_0 Lazeroms	$C_d^{1/2}\Gamma_{TS}$ tuned (50 km)	E_0 tuned (50 km)	$C_d^{1/2}\Gamma_{TS}$ tuned (offshore)	E_0 tuned (offshore)
Lazeroms formulation	5.9×10^{-4}	3.6×10^{-2}	2.1×10^{-4}	5.4×10^{-2}	10.4×10^{-4}	0.39×10^{-2}
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Maximum number of boxes	$\gamma_T^\star$ original	C original	$\gamma_T^\star$ tuned (50 km)	C tuned (50 km)	$\gamma_T^\star$ tuned (offshore)	C tuned (offshore)
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PICO boxes	2×10^{-5}	1×10^{6}	0.41×10^{-5}	15.1×10^{6}	0.70×10^{-5}	0.12×10^{6}

Variations of the box parameterisation

Variations of the PICOP parameterisation

PICOP setup	$C_d^{1/2}\Gamma_{TS}$ Lazeroms	E_0 Lazeroms	$C_d^{1/2}\Gamma_{TS}$ tuned (50 km)	E_0 tuned (50 km)	$C_d^{1/2}\Gamma_{TS}$ tuned (offshore)	E_0 tuned (offshore)
10 boxes	5.9×10^{-4}	3.6×10^{-2}	1.3×10^{-4}	3.6×10^{-2}	2.3×10^{-4}	5.6×10^{-2}
PICO boxes	5.9×10^{-4}	3.6×10^{-2}	1.8×10^{-4}	2.2×10^{-2}	1.4×10^{-4}	8.9×10^{-2}

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Variations of the plume parameterisation

Parameterisation	$C_d^{1/2}\Gamma_{TS}$ Lazeroms	E_0 Lazeroms	$C_d^{1/2}\Gamma_{TS}$ tuned (50 km)	E_0 tuned (50 km)	$C_d^{1/2}\Gamma_{TS}$ tuned (offshore)	E_0 tuned (offshore)
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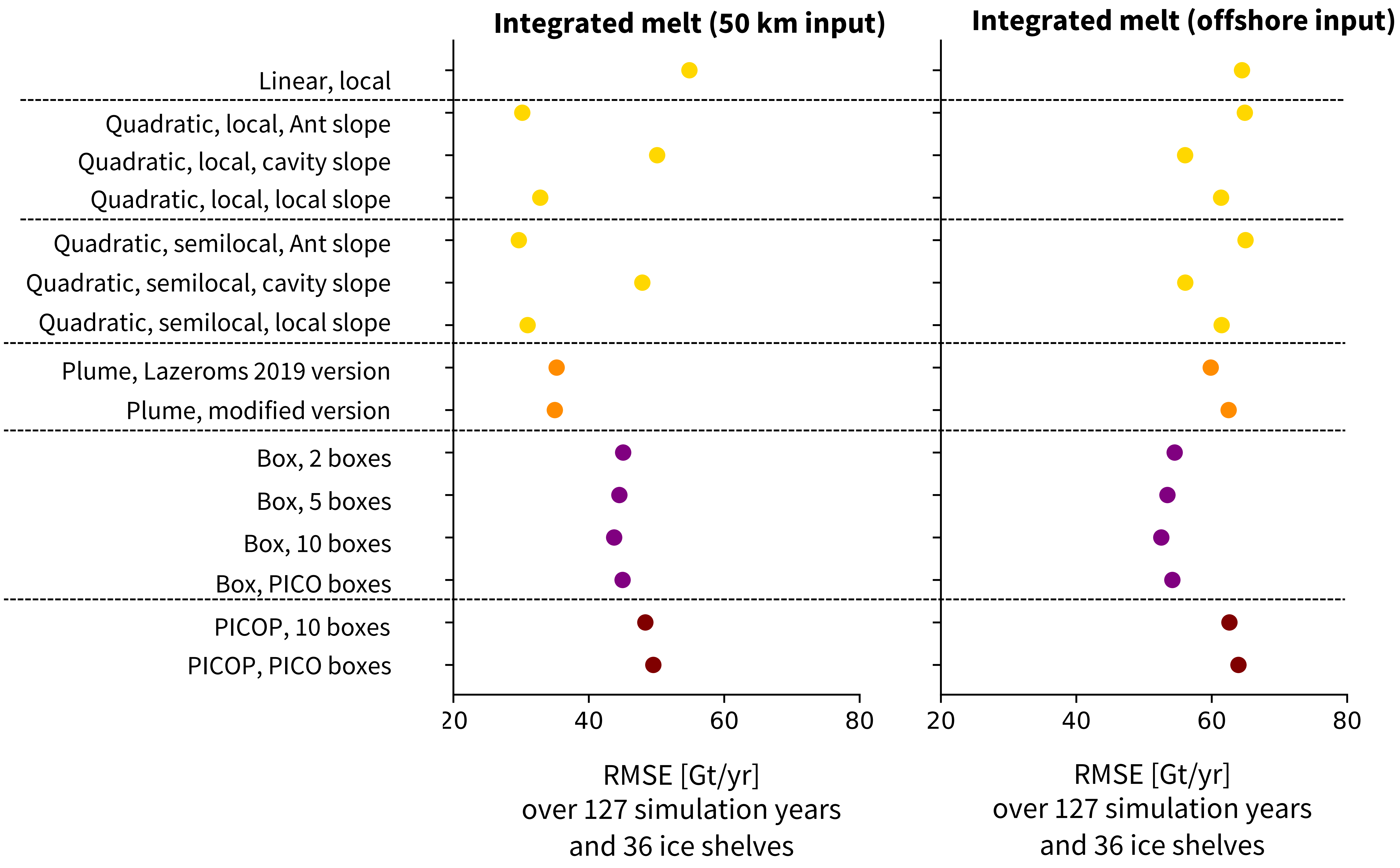
PICO boxes	2×10^{-5}	1×10^{6}	0.41×10^{-5}	15.1×10^{6}	0.70×10^{-5}	0.12×10^{6}

Variations of the box parameterisation

Variations of the PICOP parameterisation

PICOP setup	$C_d^{1/2}\Gamma_{TS}$ Lazeroms	E_0 Lazeroms	$C_d^{1/2}\Gamma_{TS}$ tuned (50 km)	E_0 tuned (50 km)	$C_d^{1/2}\Gamma_{TS}$ tuned (offshore)	E_0 tuned (offshore)
10 boxes	5.9×10^{-4}	3.6×10^{-2}	1.3×10^{-4}	3.6×10^{-2}	2.3×10^{-4}	5.6×10^{-2}
PICO boxes	5.9×10^{-4}	3.6×10^{-2}	1.8×10^{-4}	2.2×10^{-2}	1.4×10^{-4}	8.9×10^{-2}

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



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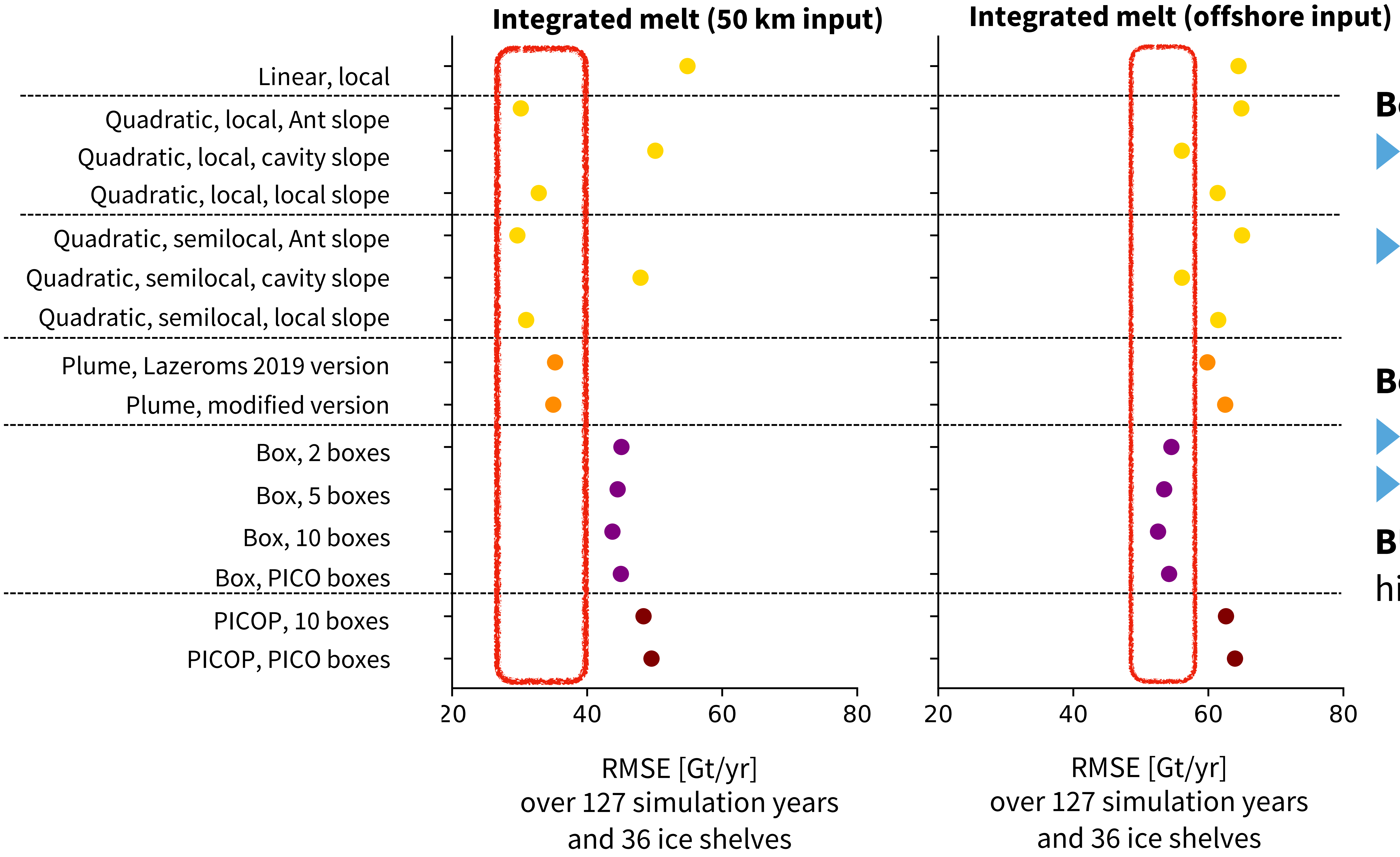


Best for 50 km input

- Quadratic parameterisation using Antarctic or local slope
- Plume parameterisation

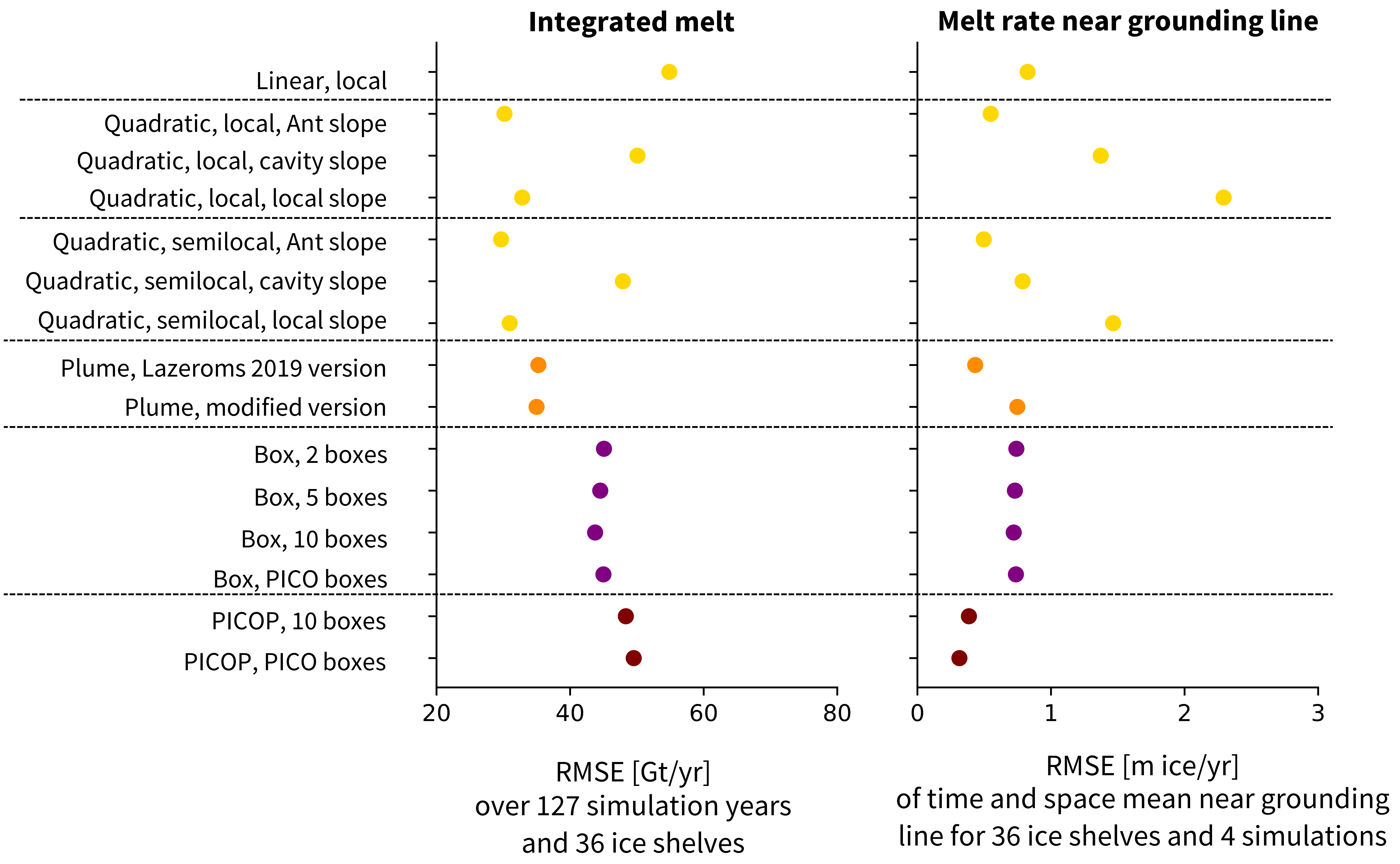
Best for offshore

- Box parameterisation
- Quadratic using cavity slope

BUT RMSE generally 10 to 40 Gt/yr higher

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



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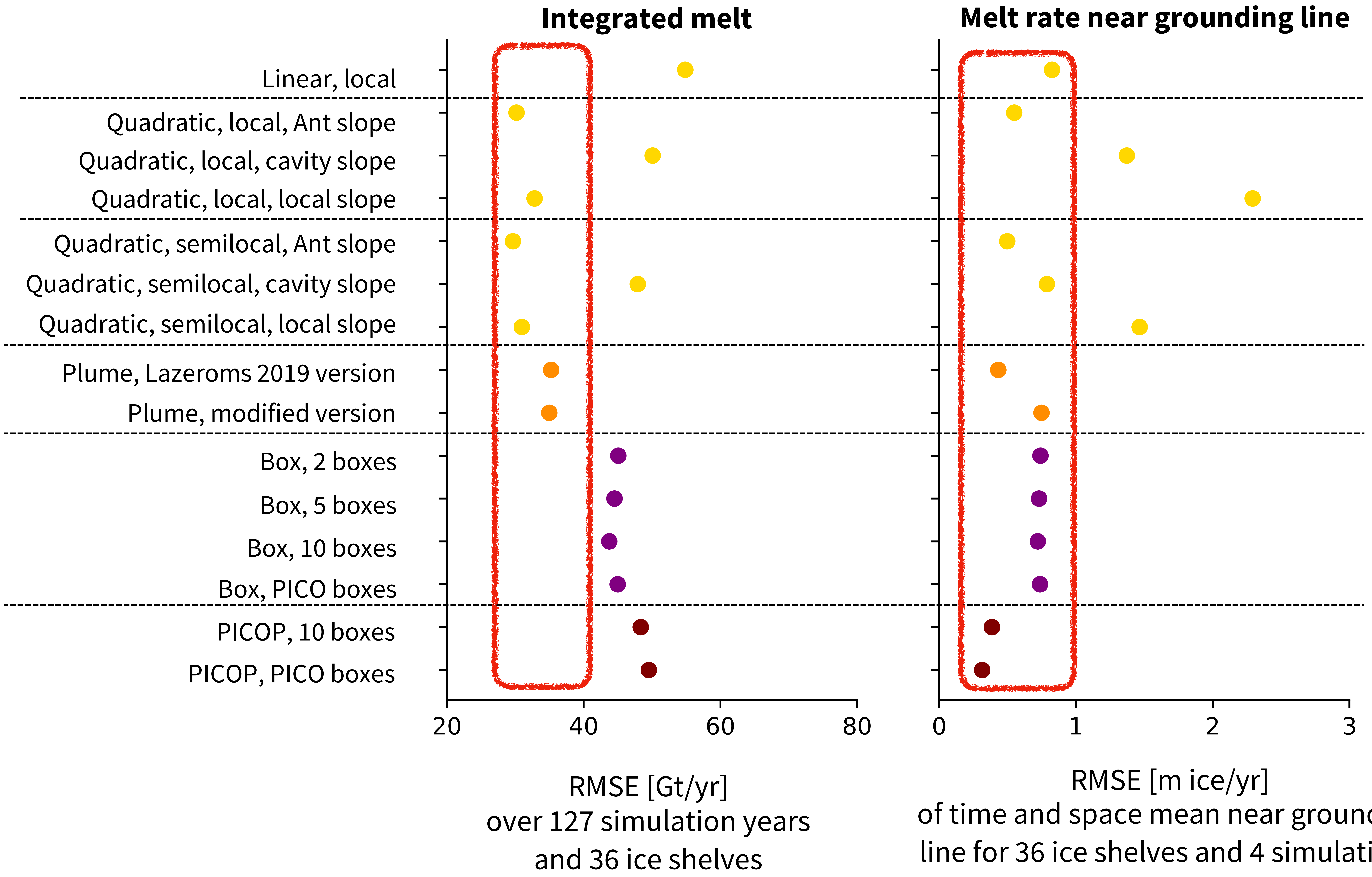


Mean reference integrated ice-shelf melt: 38 Gt/yr

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

Remember

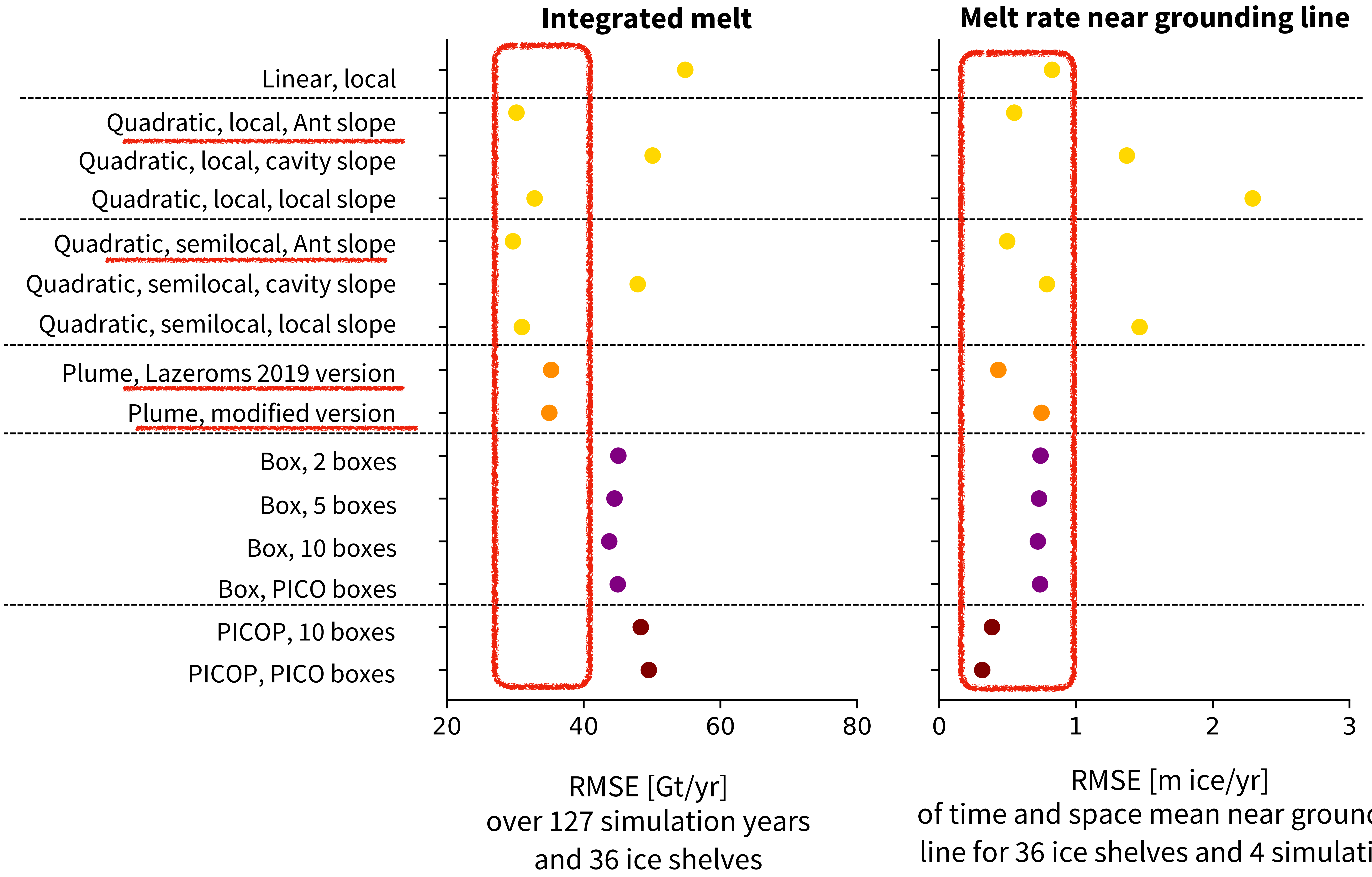
Best for integrated melt, 50 km input

- Quadratic parameterisation using Antarctic or local slope
- Plume parameterisation

Melt rate near GL

- All similar range except quadratic using local slope

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	5th	10th	33rd	Median	66th	90th	95th
Plume, Lazeroms $C_d^{1/2}\Gamma_{TS}\times10^{-4}$, 500 bootstrap samples)	1.3	1.4	1.7	1.9	2.1	2.7	3.0
Boxes, PICO boxes ($\gamma_T^{\star}\times10^{-5}$, 200 bootstrap samples)	0.21	0.24	0.37	0.45	0.57	1.54	1.96
Boxes, 10-box setup ($\gamma_T^{\star}\times10^{-5}$, 100 bootstrap samples)	0.24	0.29	0.46	0.59	0.80	1.61	2.27
PICOP, 10-box setup ($C_d^{1/2}\Gamma_{TS}\times10^{-4}$, 100 bootstrap samples)	0.96	1.0	1.5	2.7	7.2	7.8×10^2	1.7×10^5
PICOP, PICO boxes ($C_d^{1/2}\Gamma_{TS}\times10^{-4}$, 100 bootstrap samples)	0.95	1.1	2.1	4.9	7.3	9.1×10^4	12×10^4

Parameterisation	5th	10th	33rd	Median	66th	90th	95th
Linear-local ($\times10^{-6}$)	2.0	2.0	2.3	2.5	2.9	6.0	8.0
Quadratic-local Ant slope ($\times10^{-5}$)	9.5	9.8	11.2	12.1	13.1	15.3	15.9
Quadratic-local cavity slope ($\times10^{-5}$)	4.1	4.6	5.9	6.6	7.4	8.8	9.3
Quadratic-local local slope ($\times10^{-5}$)	7.1	7.5	8.5	8.9	9.3	9.8	10.0
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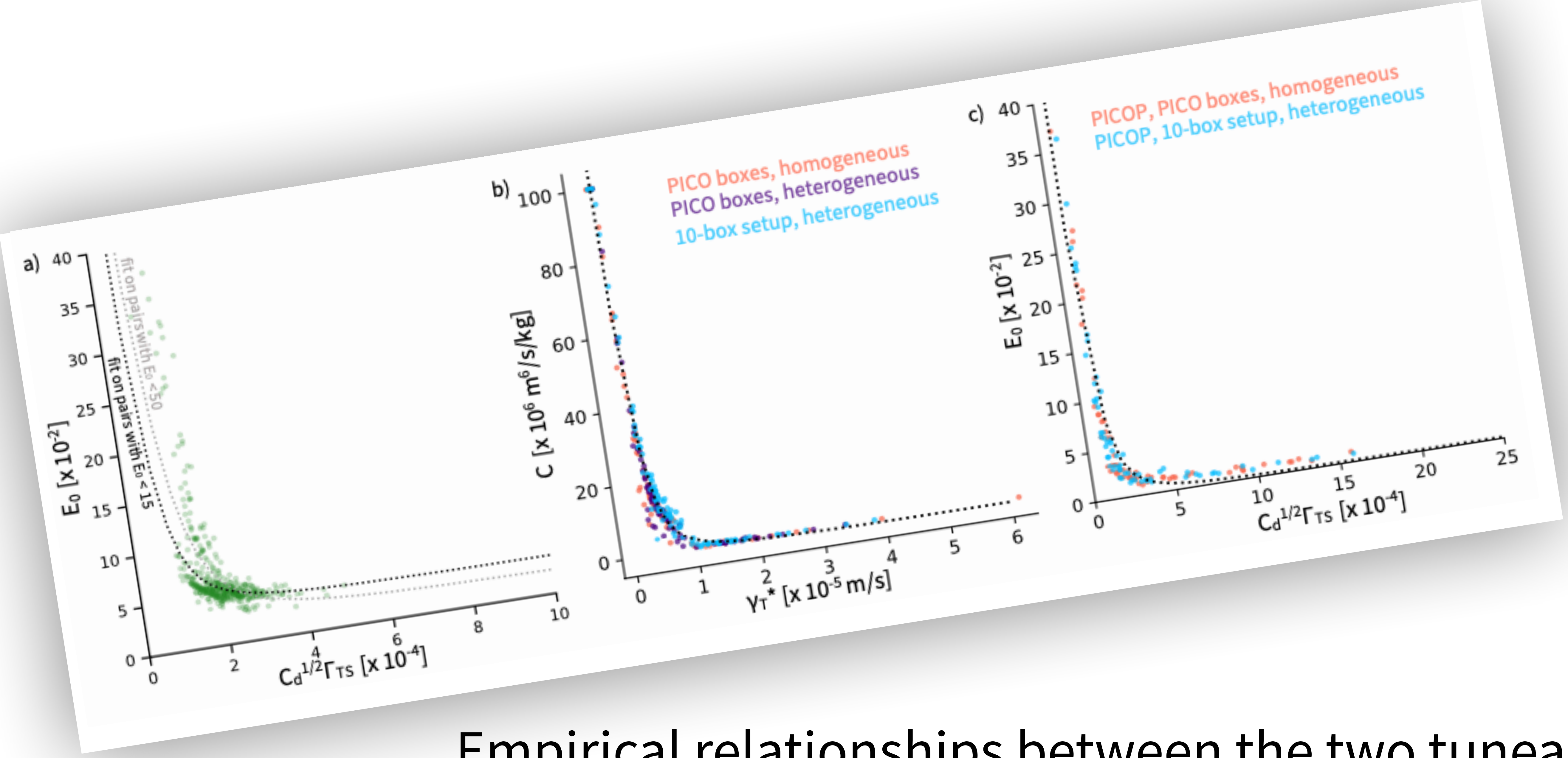

Empirical relationships between the two tuneable parameters of the complex parameterisations

More to look forward to in our preprint…

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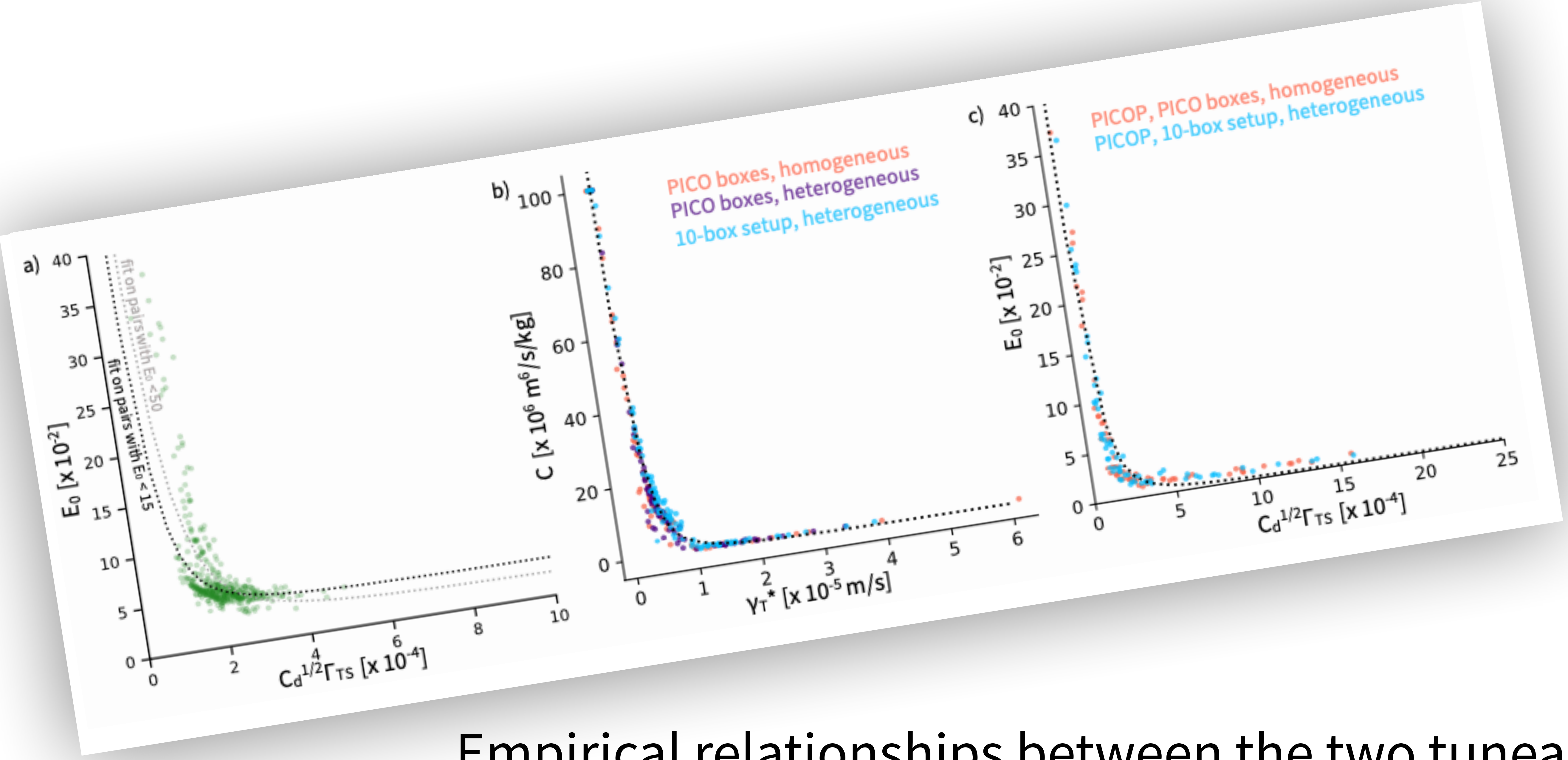


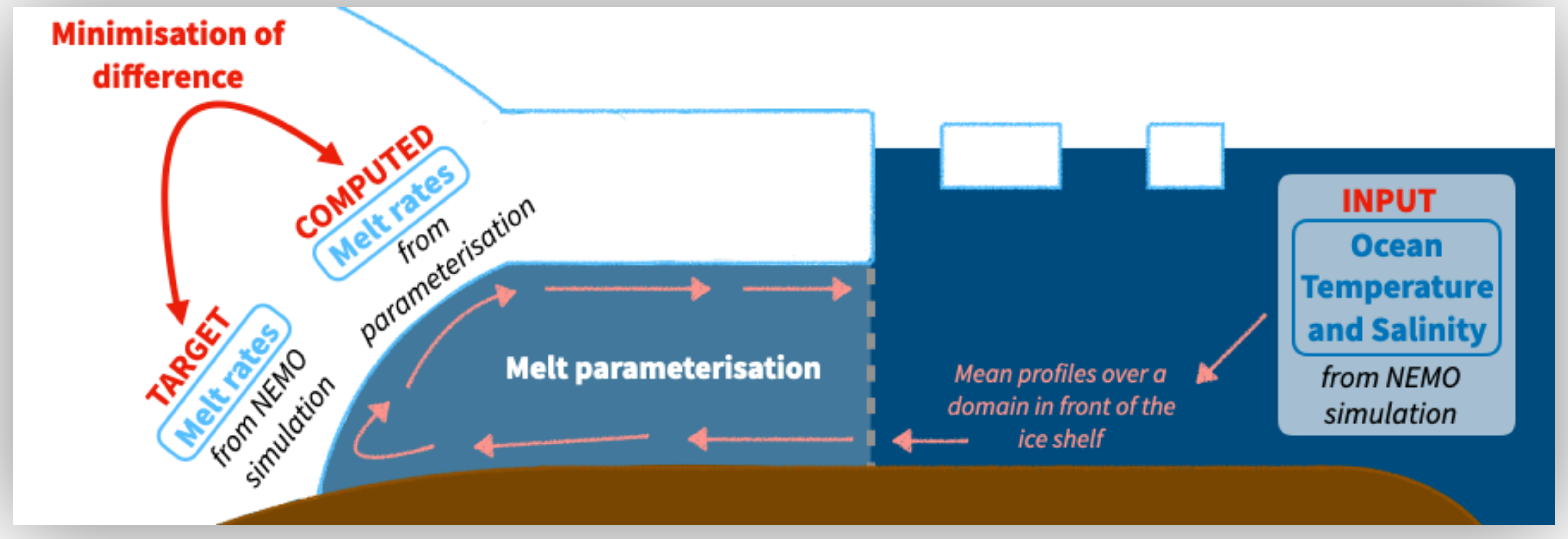
Empirical relationships between the two tuneable parameters of the complex parameterisations

And … check out our python package!

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

What you should take home…

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



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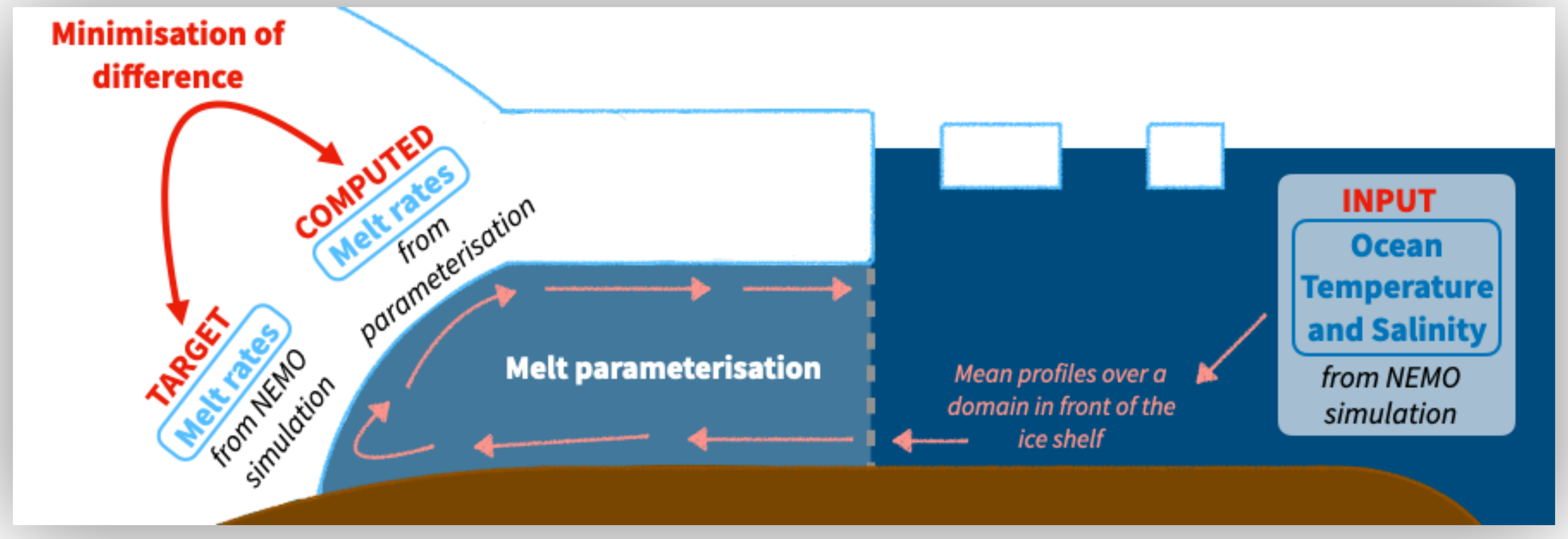

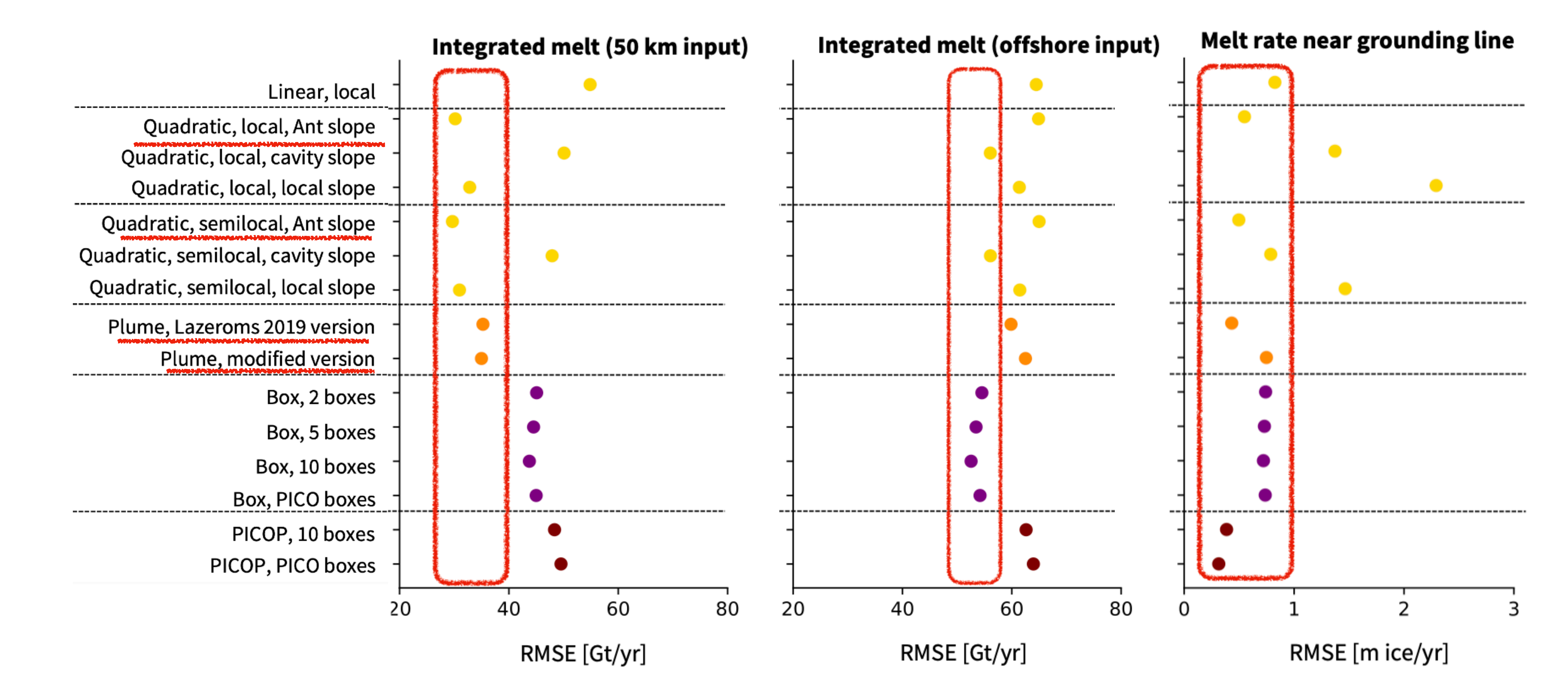

All parameterisations result in **high RMSE compared to the reference** even after re-tuning

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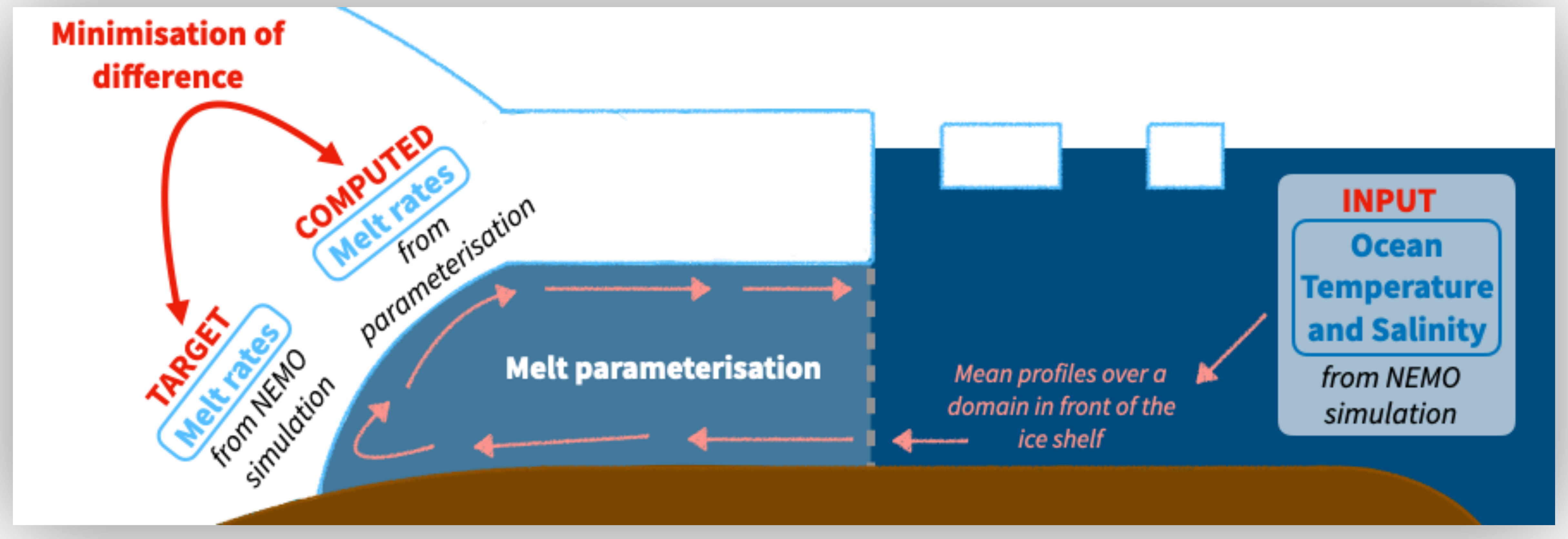

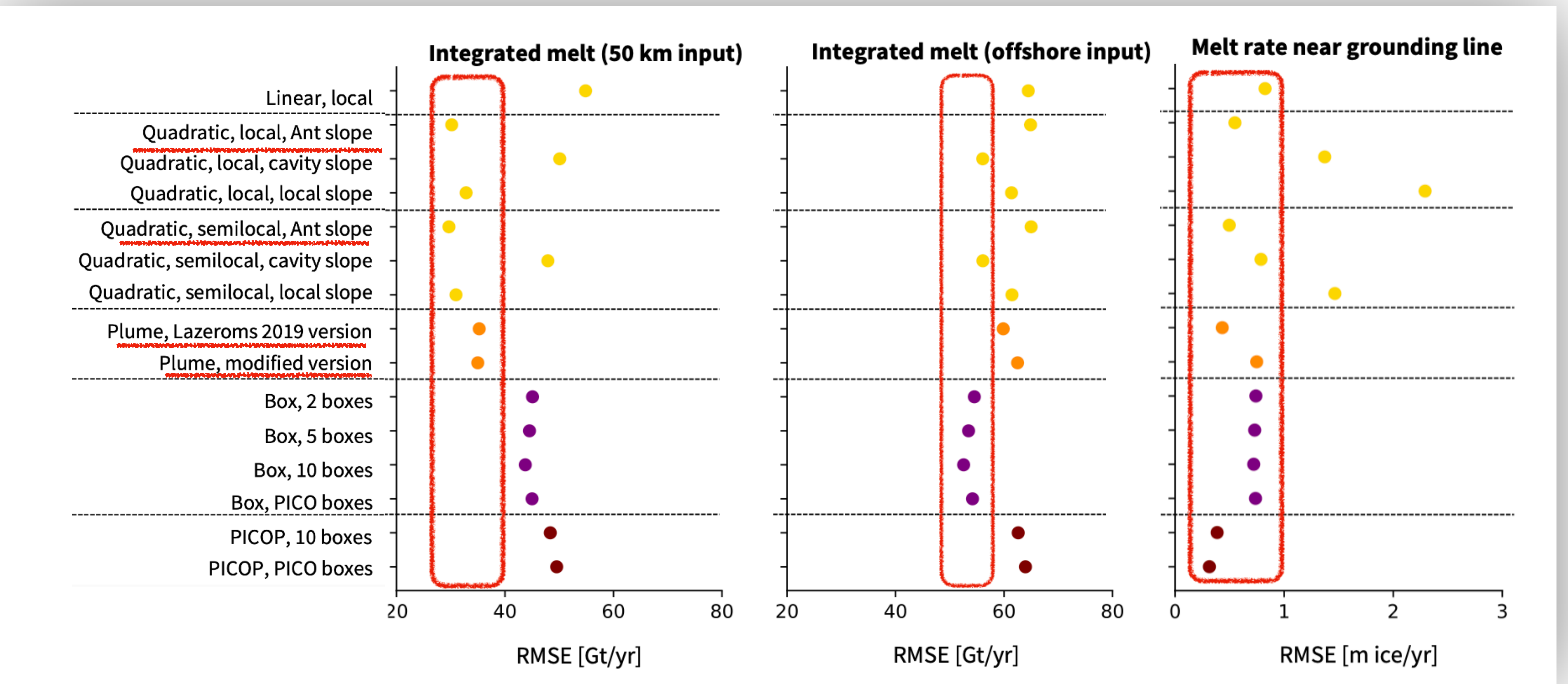

All parameterisations result in **high RMSE compared to the reference** even after re-tuning

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

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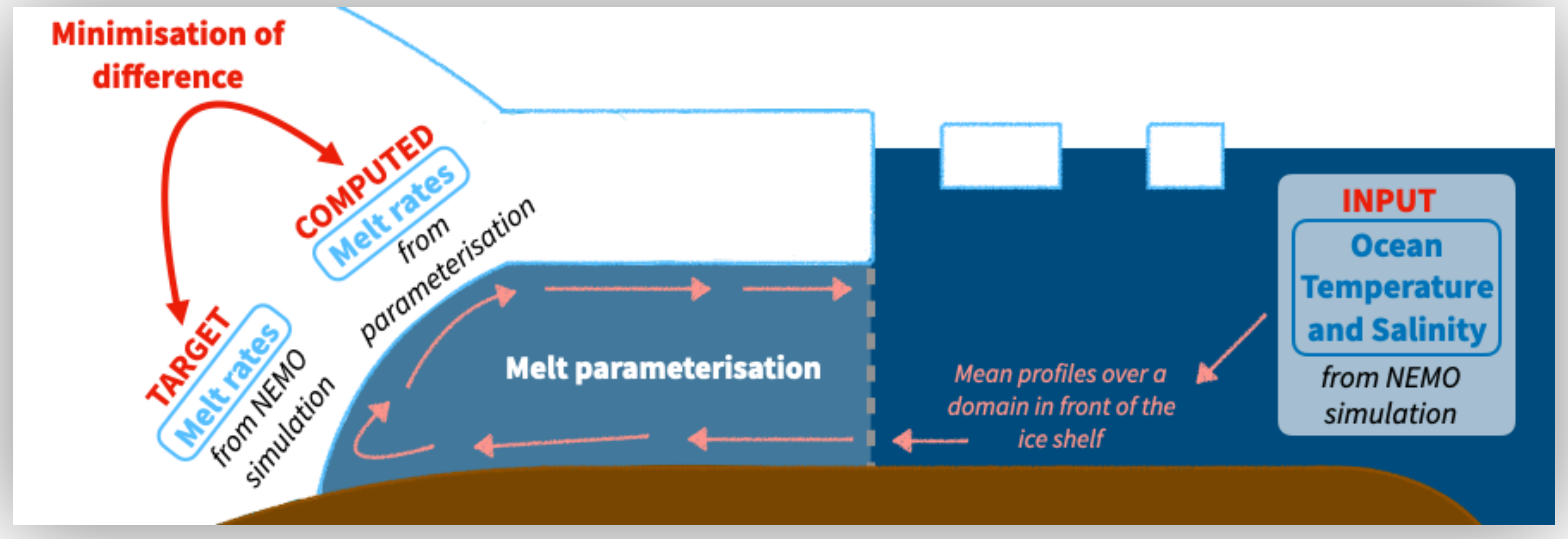
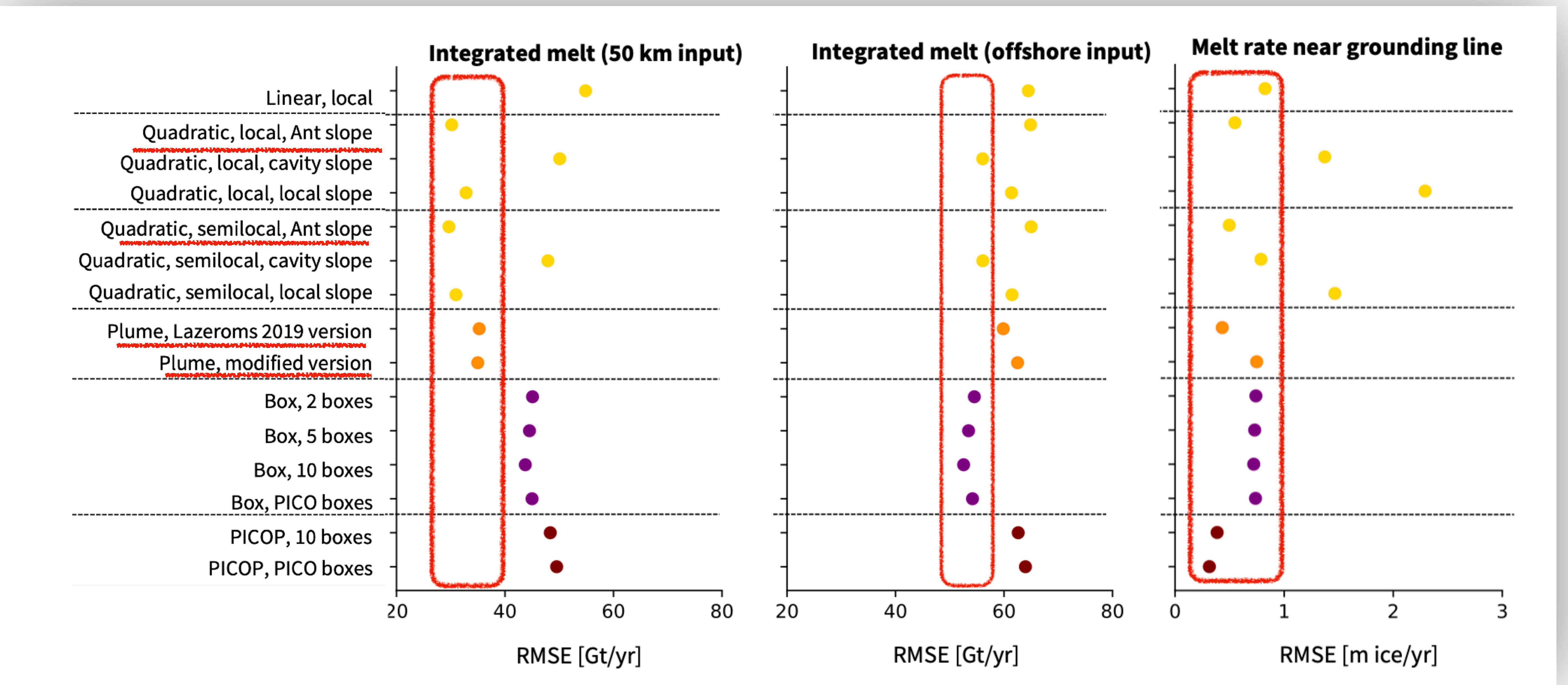
What you should take home…

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.

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