

Can we constrain the past and futures ice shelves? the basal melting calculation

Florence Colleoni¹, Aurélien Quiquet², Enea Montoli¹, Verena Haid¹

¹Centro-Euro Mediterraneo sui Cambiamenti Climatici (CMCC, Italy)

²Laboratoire des Sciences du Climat et de l'Environnement (LSCE, France)

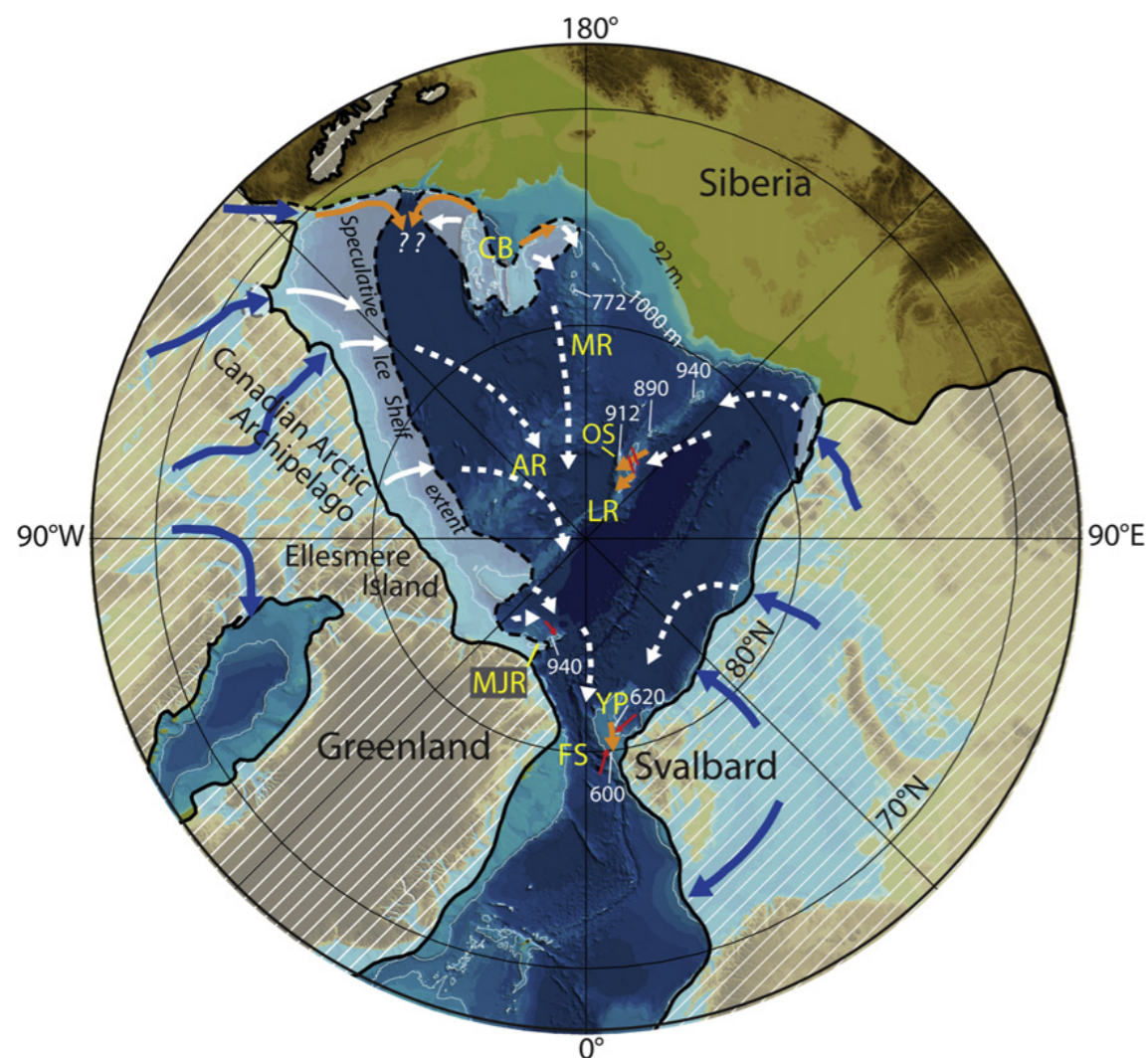


Ice shelves in the past

An Arctic Ocean ice shelf during MIS 6 constrained by new geophysical and geological data

Martin Jakobsson^{a,*}, Johan Nilsson^b, Matthew O'Regan^a, Jan Backman^a, Ludvig Löwemark^a, Julian A. Dowdeswell^c, Larry Mayer^d, Leonid Polyak^e, Florence Colleoni^{a,f}, Leif G. Anderson^g, Göran Björk^h, Dennis Darbyⁱ, Björn Eriksson^a, Daniela Hanslik^a, Benjamin Hell^a, Christian Marcussen^j, Emma Sellén^a, Åsa Wallin^a

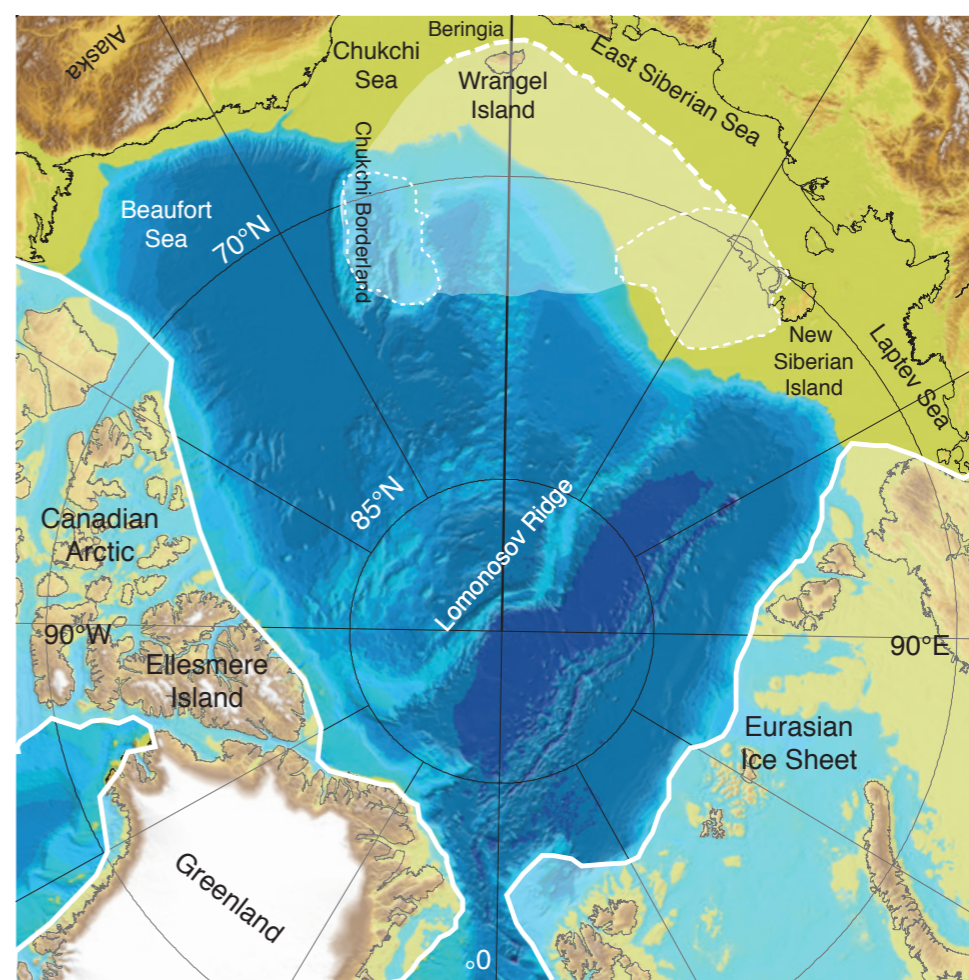
M. Jakobsson et al. / Quaternary Science Reviews 29 (2010) 3505–3517



Repeated Pleistocene glaciation of the East Siberian continental margin

Nature Geoscience, 2013, vol. 6, no 10, p. 842-846

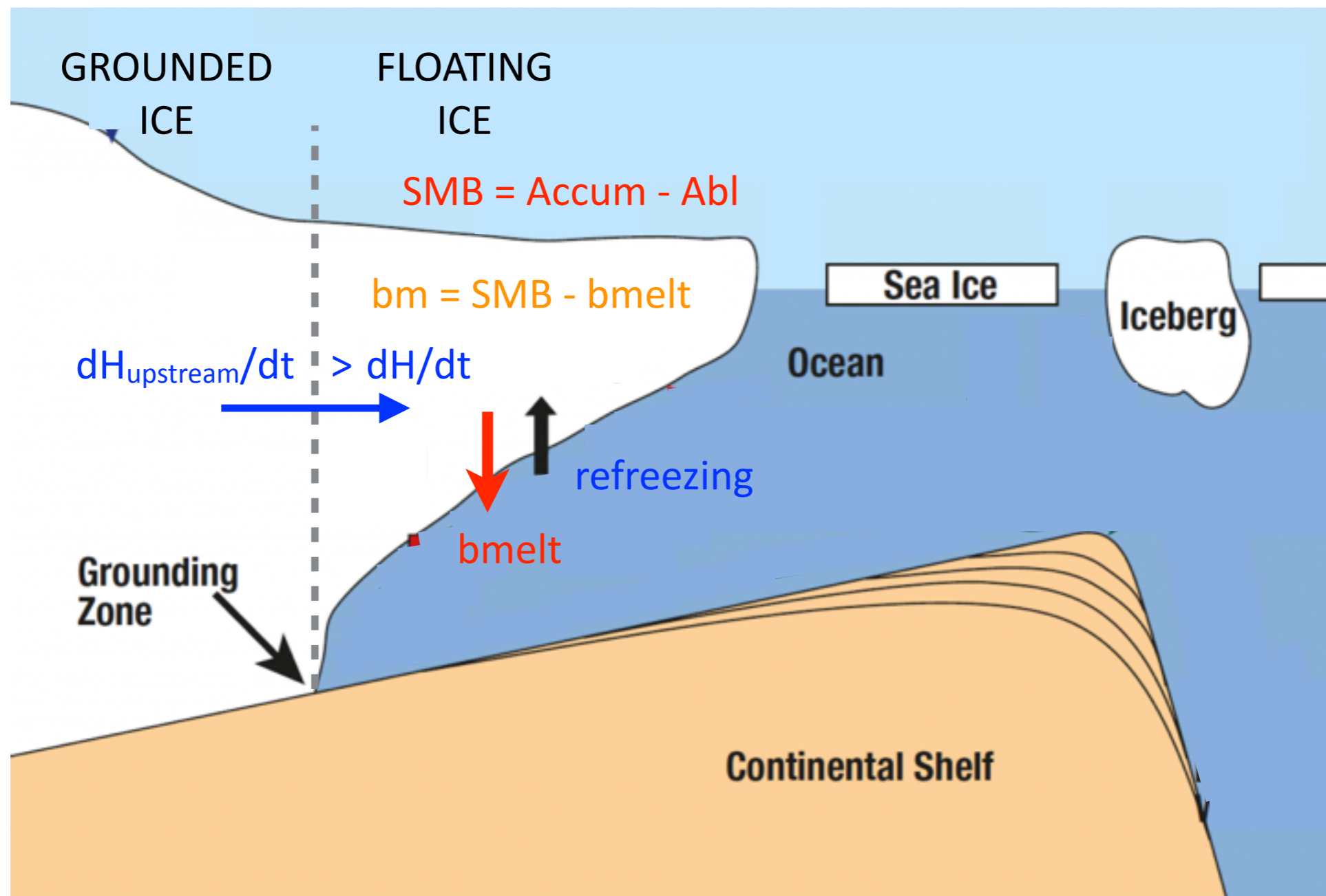
Frank Niessen^{1*}, Jong Kuk Hong^{2*}, Anne Hegewald¹, Jens Matthiessen¹, Rüdiger Stein¹, Hyoungjun Kim², Sookwan Kim^{2,3}, Laura Jensen¹, Wilfried Jokat¹, Seung-Il Nam² and Sung-Ho Kang²



Large uncertainties on ice shelves extent and timing



Choice of basal melting: ice shelf mass balance



- Ice flux from grounded ice can not feed the ice shelf

Calving if:

and/or

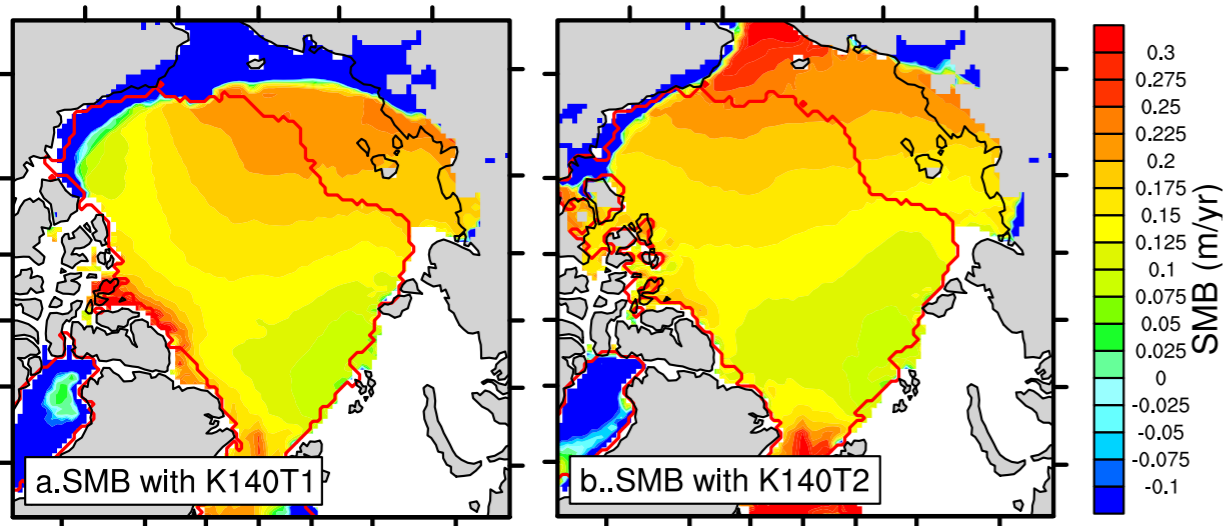
- ice shelf mass balance is negative



Choice of basal melting: ice shelf mass balance

MIS6 big Laurentide

MIS6 small Laurentide



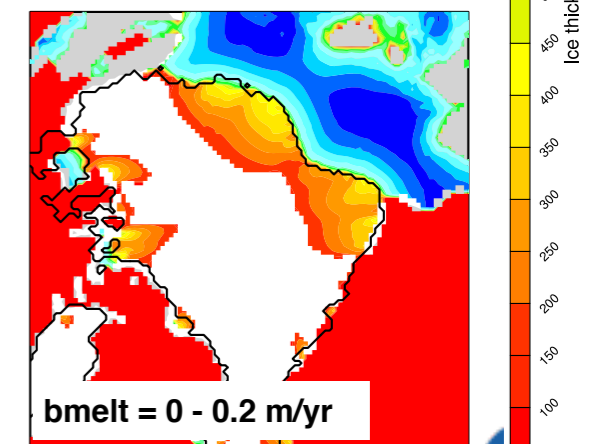
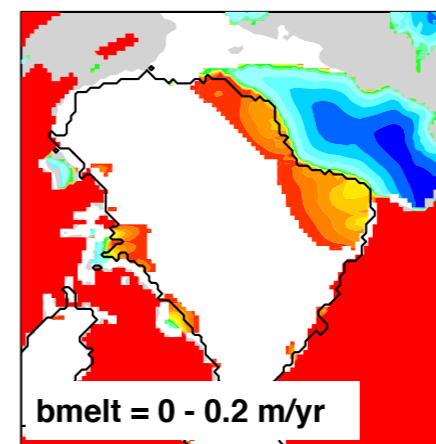
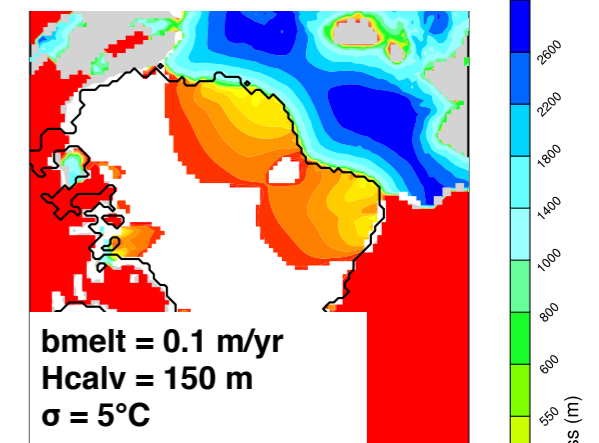
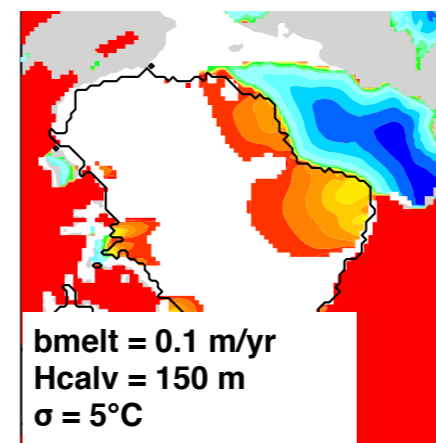
To grow some ice shelves you need to consider:

- **basal melting** values lower than ~ 0.15 /myr
- **a reasonable calving** cutting threshold



BUT

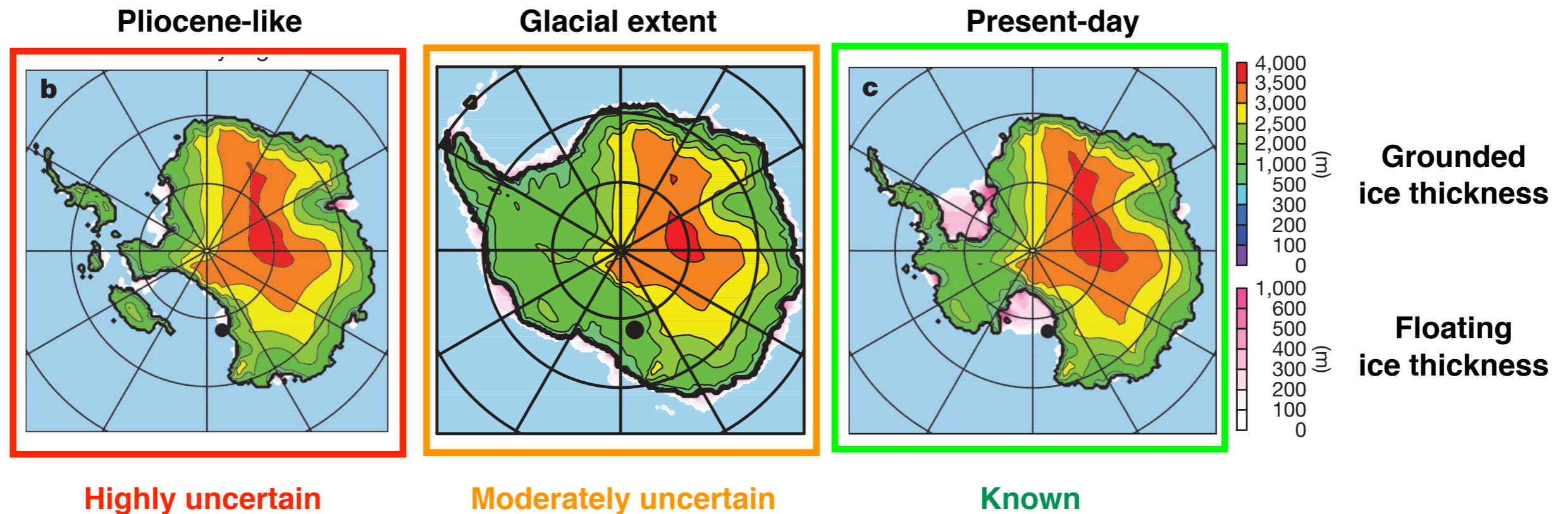
Now we are prescribing values to get the expected result!



Modelling West Antarctic ice sheet growth and collapse through the past five million years

David Pollard¹ & Robert M. DeConto²

Vol 458|19 March 2009|doi:10.1038/nature07809



Some confidence about ice shelves history



ANDRILL-MIS sediments record

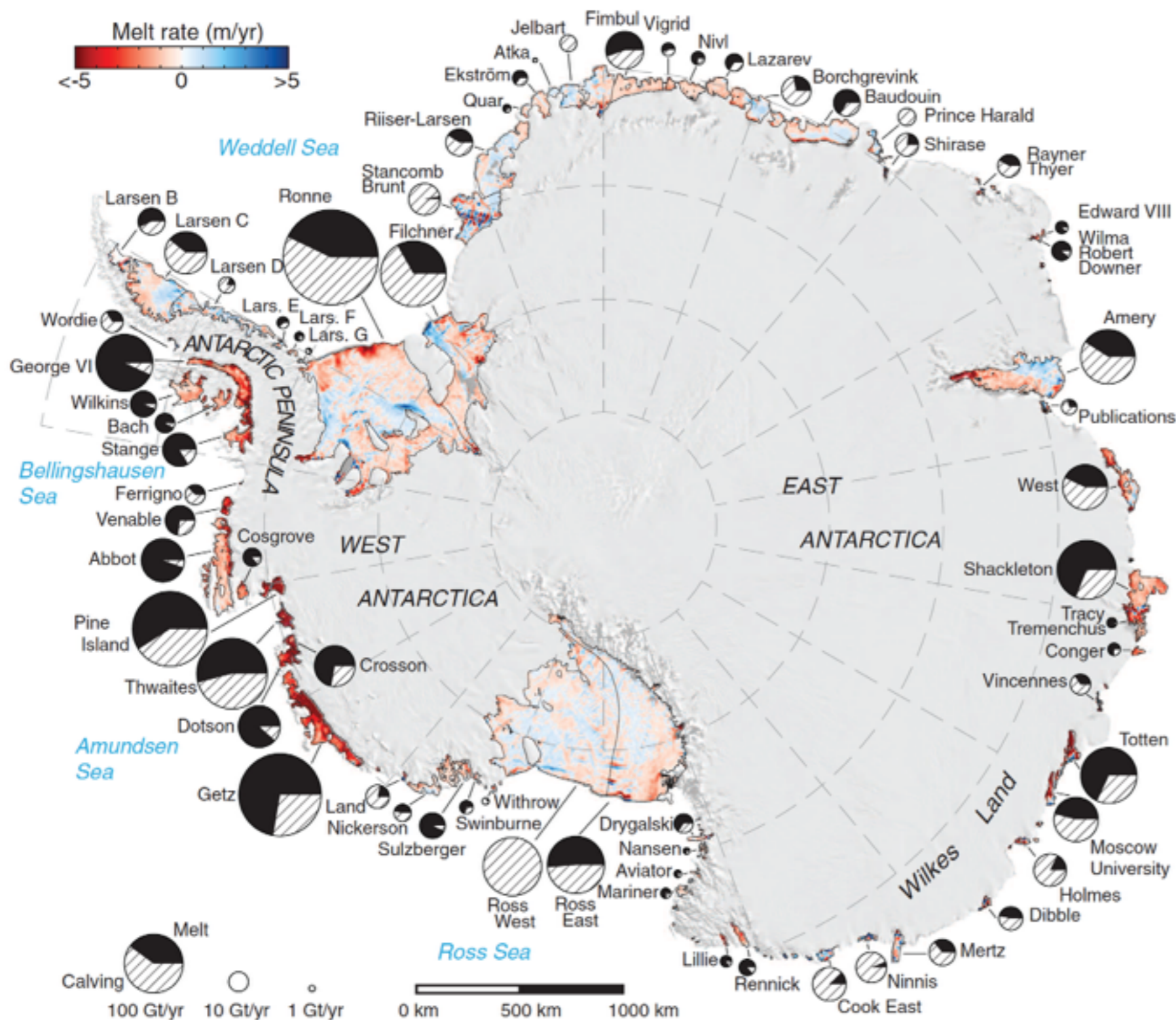


Current ice shelves

Ice-Shelf Melting Around Antarctica

E. Rignot *et al.*

Science **341**, 266 (2013);



Basal melt rates inferred from the observations of:

- dH_{upstream}/dt
- $\text{SMB} = \text{Accum} - \text{Abl}$

+

Observations of ocean state



Parametrisations/
formulations of
basal melting



Basal melting: the questions

In the context of **stand alone ice-sheet*** modelling:

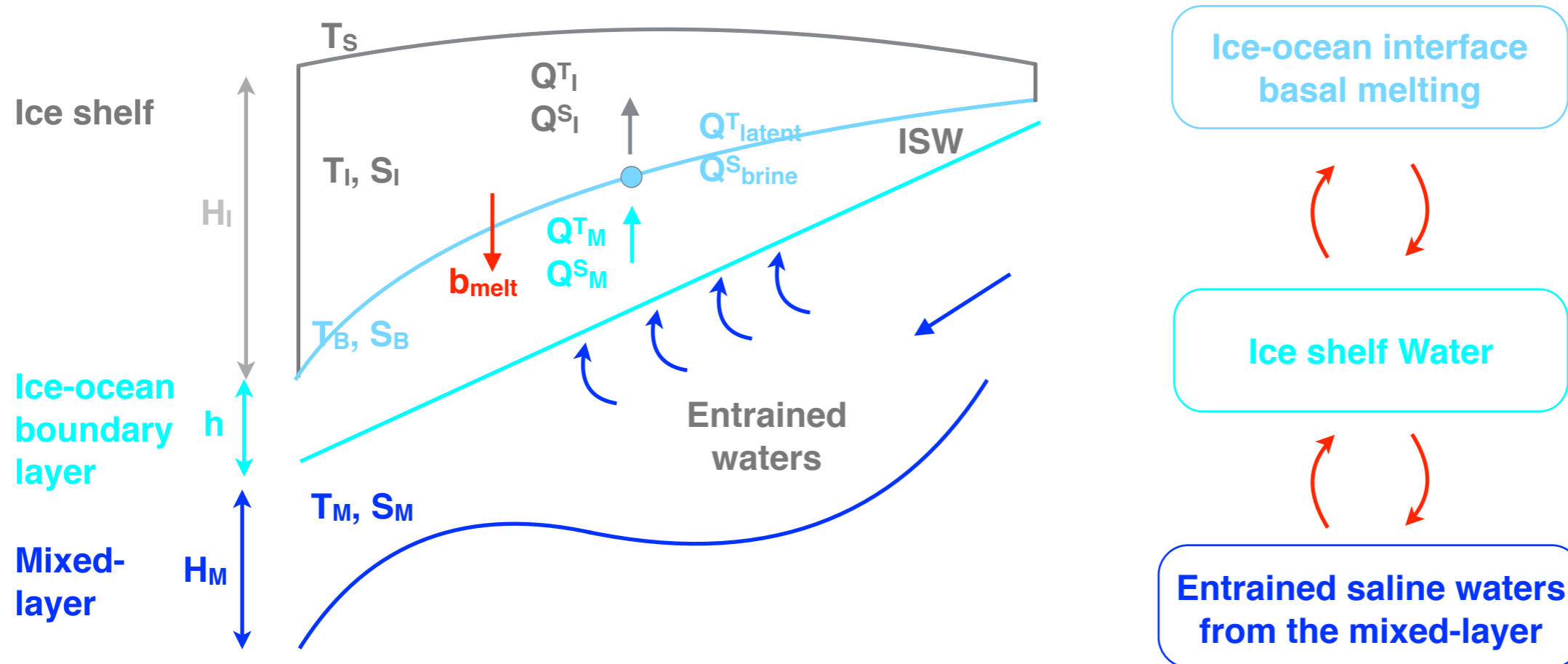
*ice-ocean coupling is still partial: no dynamic land-sea mask

*need the stand-alone ice sheet models to compute projections and past ice sheets

- Do parametrisations help providing some constraints?
- How to choose the basal melting formulation?



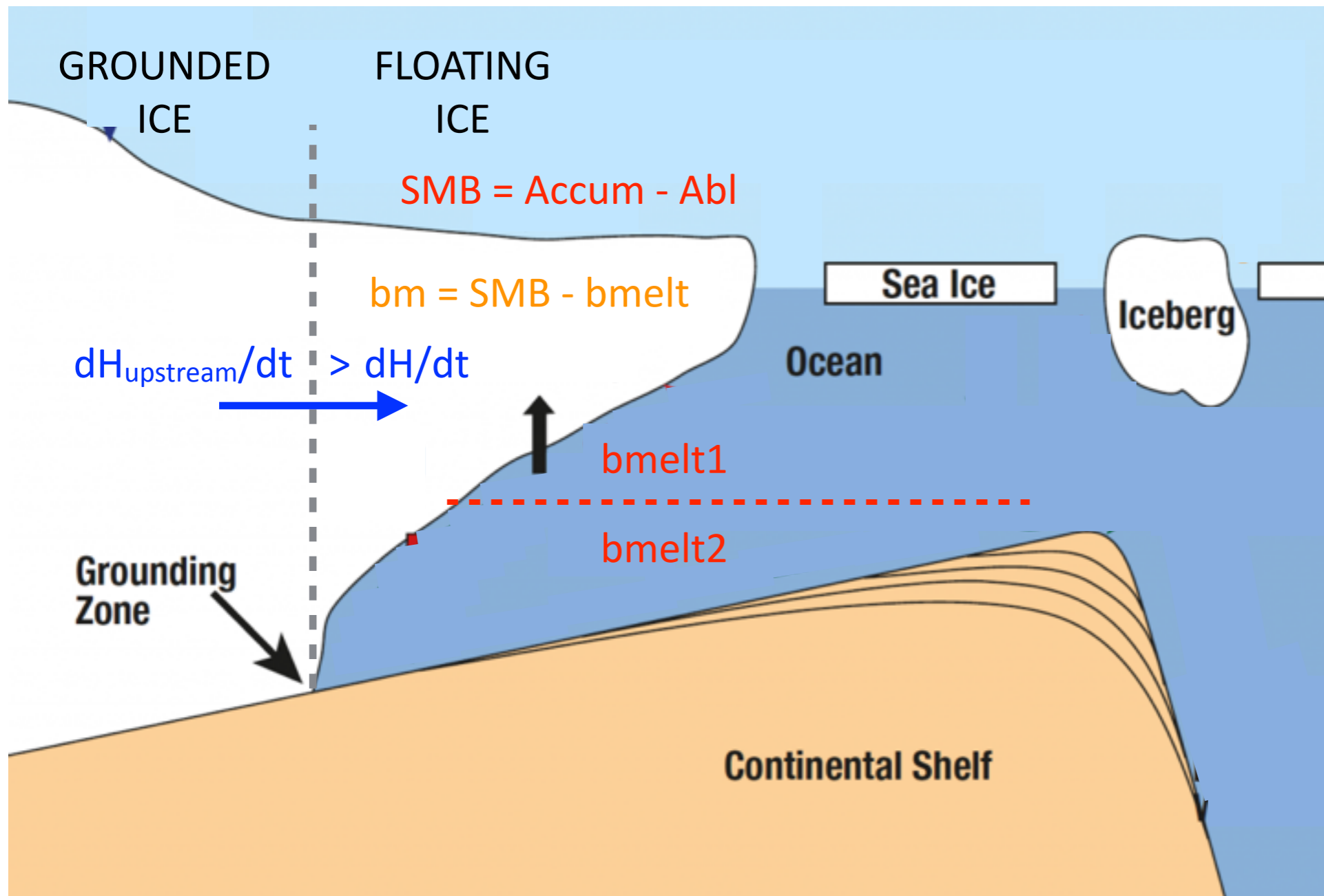
Basal melting: Ice shelf - ocean circulation cavity system



ISW: Ice Shelf Water



Basal melting: simplest parametrisation



Limitations:

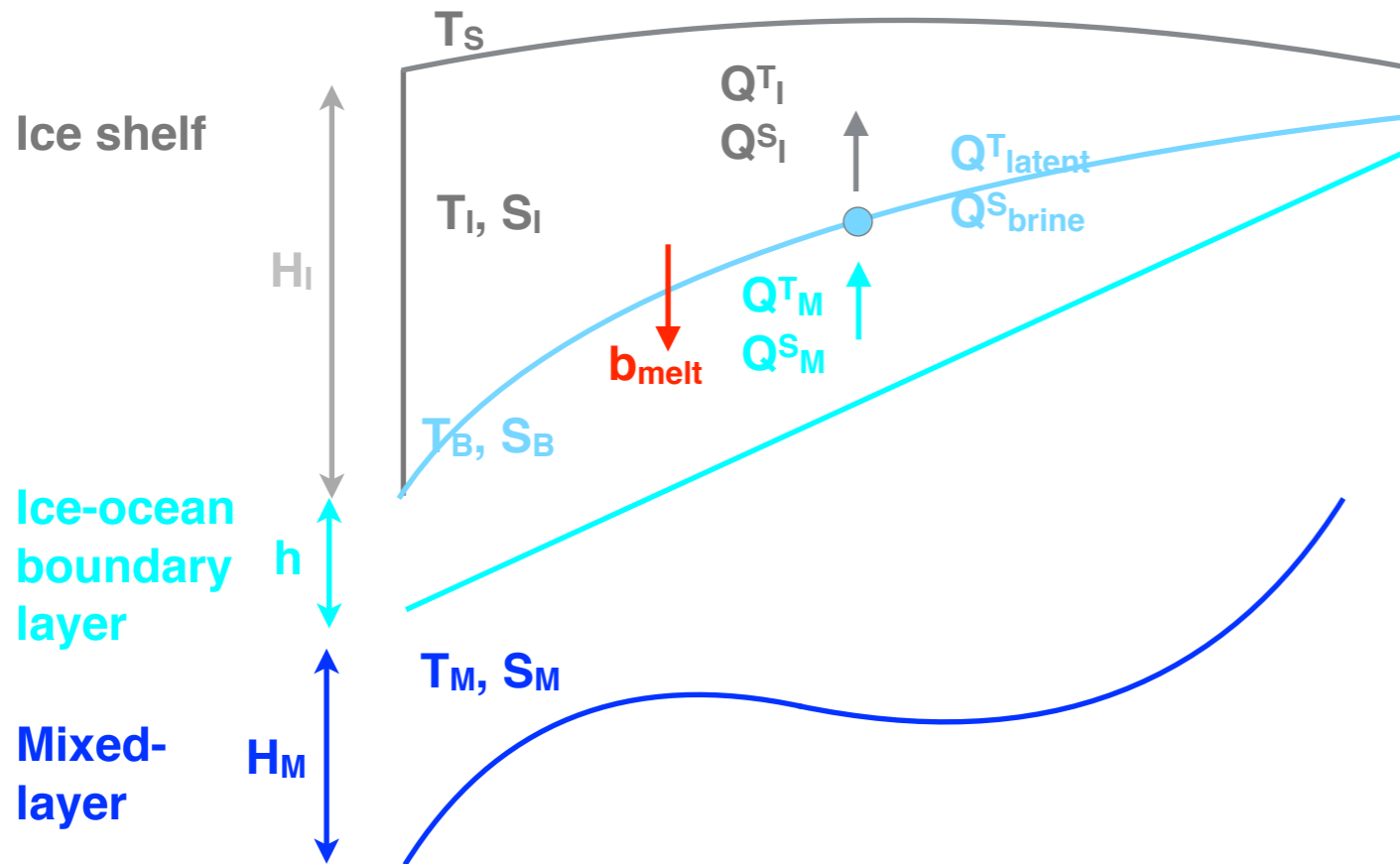
- No refreezing
- uniform values for an entire hemisphere or regions
- uniform values in function of depth
- How to determine the depth threshold?

↓
incorrect
representation
of the ice-ocean
boundary layer



Basal melting: three equations formulation

Holland and Jenkins (1999):



$$(1) \quad Q_{latent} = Q_I^T + Q_M^T$$

$$Q_I^T = -\rho_i c_{pI} \kappa_I \frac{T_S - T_B}{H_I}$$

$$Q_M^T = -\rho_M c_{pI} \gamma_T (T_B - T_M)$$

$$(2) \quad Q_{brine}^S = Q_I^S + Q_M^S$$

$$Q_I^S = 0 \quad \text{No salt diffusion within the ice shelf}$$

$$Q_M^S = -\rho_M \gamma_S (S_B - S_M)$$

↓
salinity
exchange
velocity

Exchange velocities:

γ_T

γ_S

both depend on the friction velocity u^*

$$u^* = c_d U_M^2$$

drag
coeff.

ML
velocity

$$(3) \quad T_b = 0.0939 - 0.057 S_b + 7.64 \times 10^{-4} Z_b$$



Basal melting: examples

Holland and Jenkins (1999): Three equations formulations

$$bmelt = \left[\rho_W c_W \gamma_T (T - T_b) + \rho_I c_I \kappa_I \left. \frac{\delta T_I}{\delta z} \right|_b \right] / (L * \rho_I)$$

$$bmelt = \frac{\rho_W \gamma_S (S - S_b)}{\rho_I S_b}$$

$$T_b = 0.0832 - 0.057 S_b + 7.61 \times 10^{-4} \times z_b$$

γ_T, γ_S Thermal and salinity exchange velocities

T_I Ice shelf temperature

z_b Ice shelf depth

T, S Ocean temperature and salinity

no plume

Martin et al.(2011): Two equations formulations (infinite salt diffusivity)

$$bmelt = \rho_W c_W \gamma_T F_{melt} \frac{(T - T_f)}{L \rho_i} \quad F_{melt} = 0.005$$

$$T_f = 273.15 + 0.0939 - 0.057 S_o + 7.64 \times 10^{-4} z_b .$$

Pollard and Deconto (2012): Two equations formulations (Martin et al. 2011 + adds on)

$$bmelt = \rho_W c_W K' \gamma_T F_{melt} |T' - T_f| \frac{(T' - T_f)}{L \rho_i}$$

$$T' = T w_a + (-1.7)(1 - w_a)$$

$$K' = K w_a + (-1.7)(1 - w_a)$$

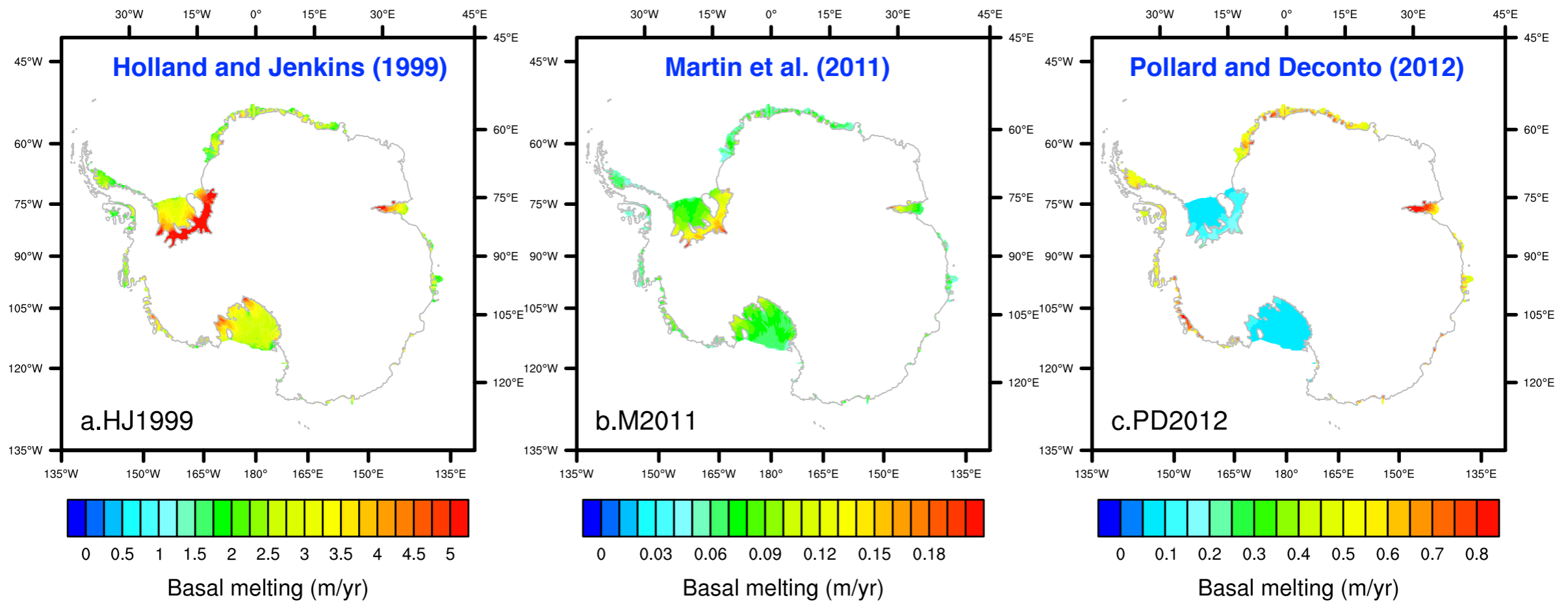
$$w_a = \max[0, \min[1, (A_a - 50)/20]]$$

A_a = subtended arc-to-ocean angle

K = 1 or 8 according to the type of ice shelf



Basal melting: Present-day Antarctica



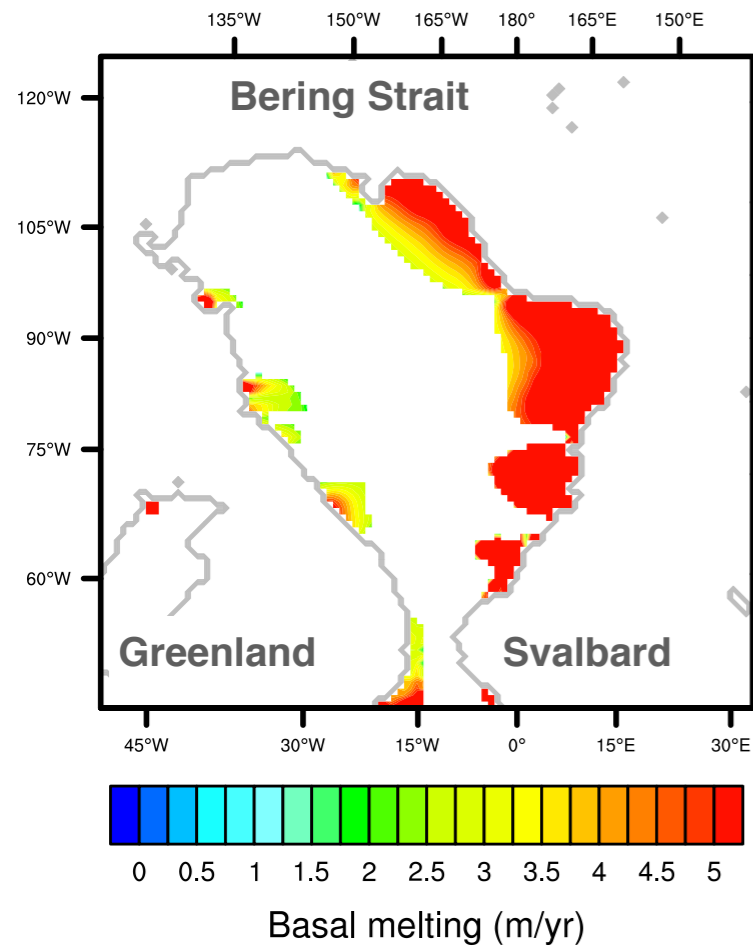
One order magnitude difference between Martin et al. (2011) and the two other methods

Pollard and Deconto (2012) is in **better agreement** with observations than the other two methods

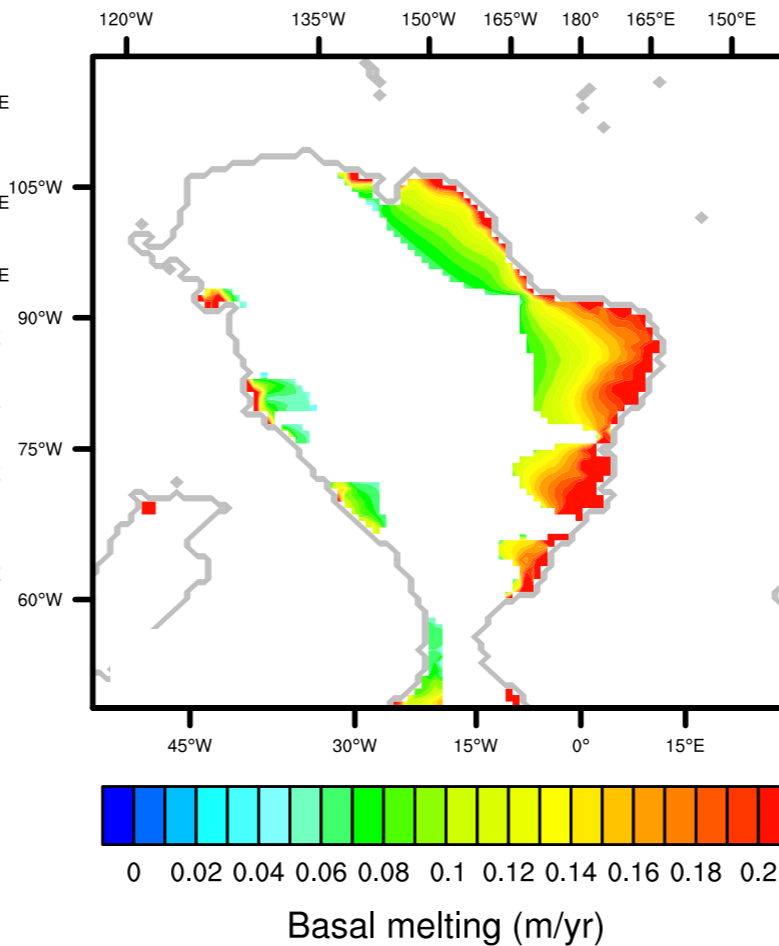


Basal melting: Penultimate glaciation in Arctic

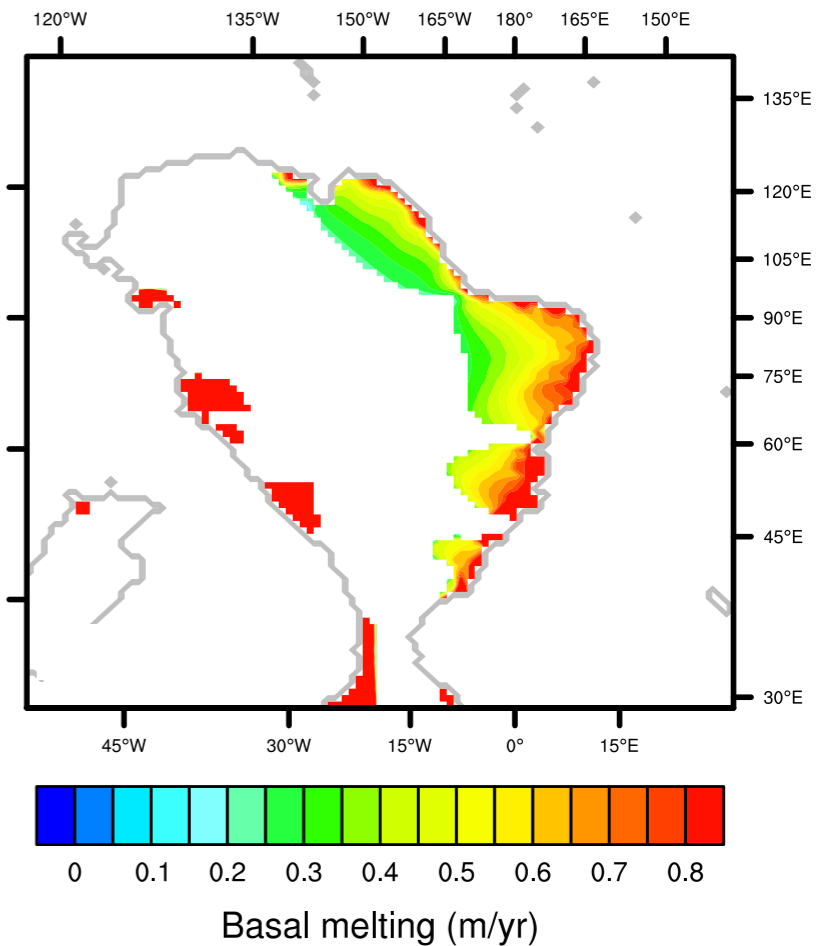
Holland and Jenkins (1999)



Martin et al. (2011)



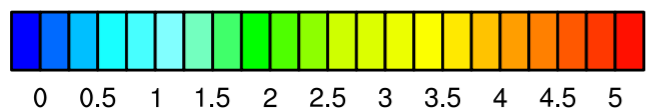
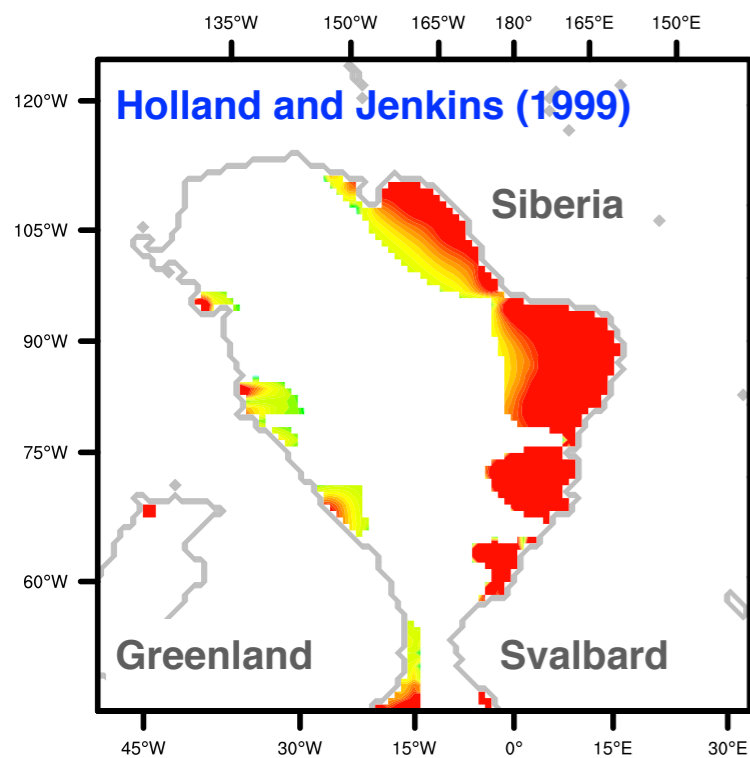
Pollard and Deconto (2012)



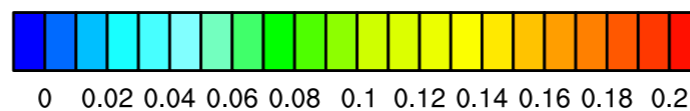
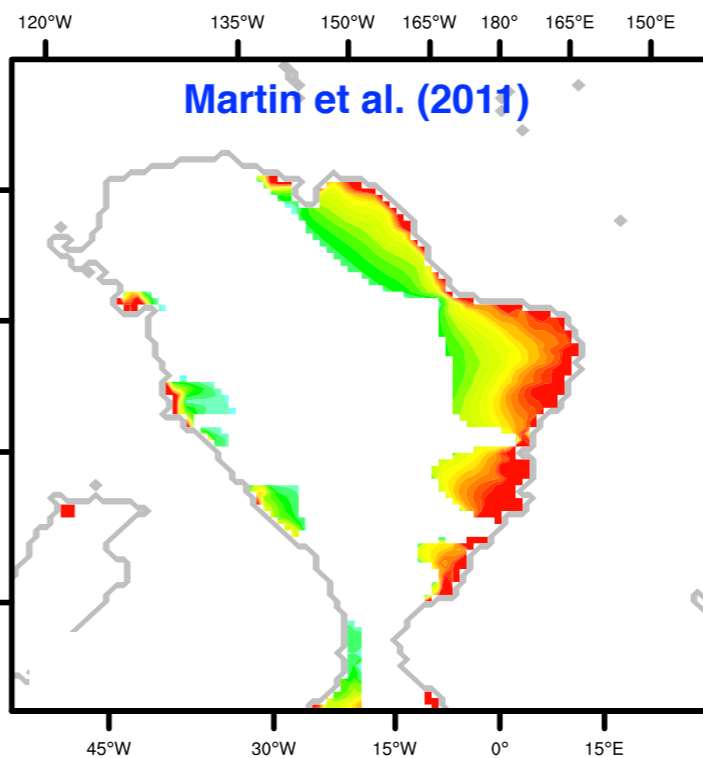
Martin et al. (2011) seems more reasonable than the others



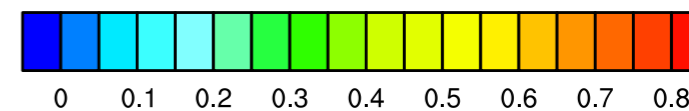
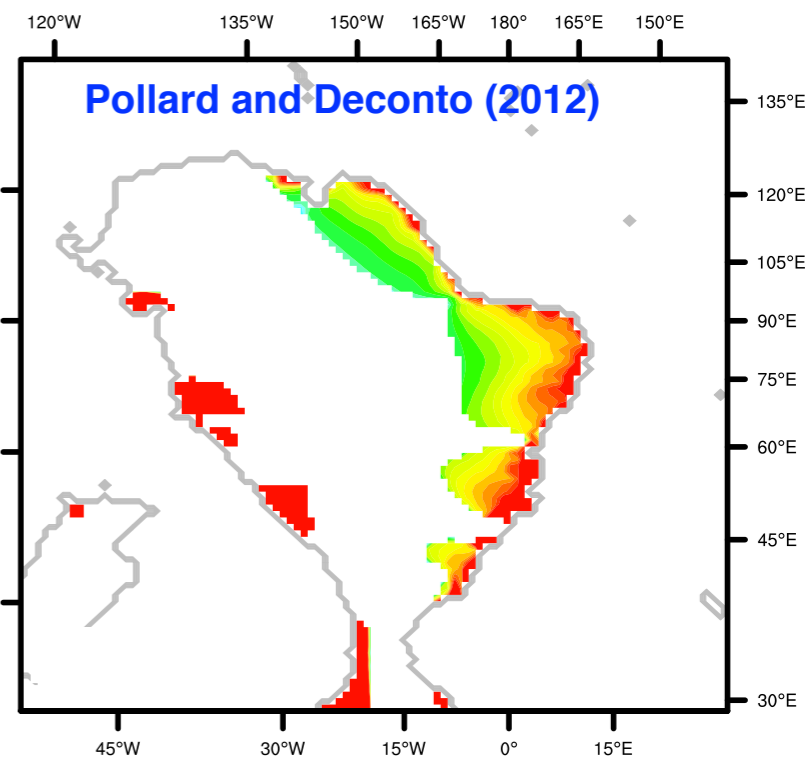
Basal melting: Last Glacial Maximum Arctic



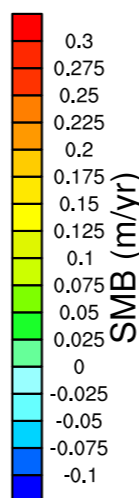
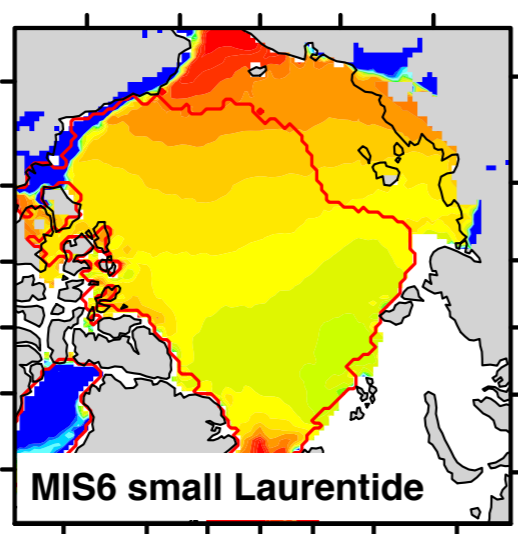
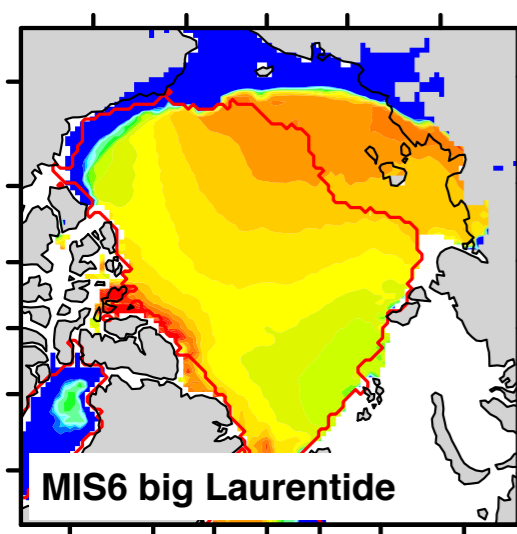
Basal melting (m/yr)



Basal melting (m/yr)



Basal melting (m/yr)



SMB (m/yr)

To grow ice shelves:

basal melting < SMB (~0.15 m/yr)



Conclusions

- The different existing methods do not converge, unless tuning
- Present-day Antarctica: the methods have to be tuned to each ice shelves
- The methods yields different basal melt rates even in the glacial Arctic
- The best methods for Antarctica present-day is that of Pollard and Deconto (2012)
The best methods for glacial Arctic is that of Martin et al. (2011) if we want some ice shelves to grow

What will be the best parametrisation of basal melting for the future?

