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

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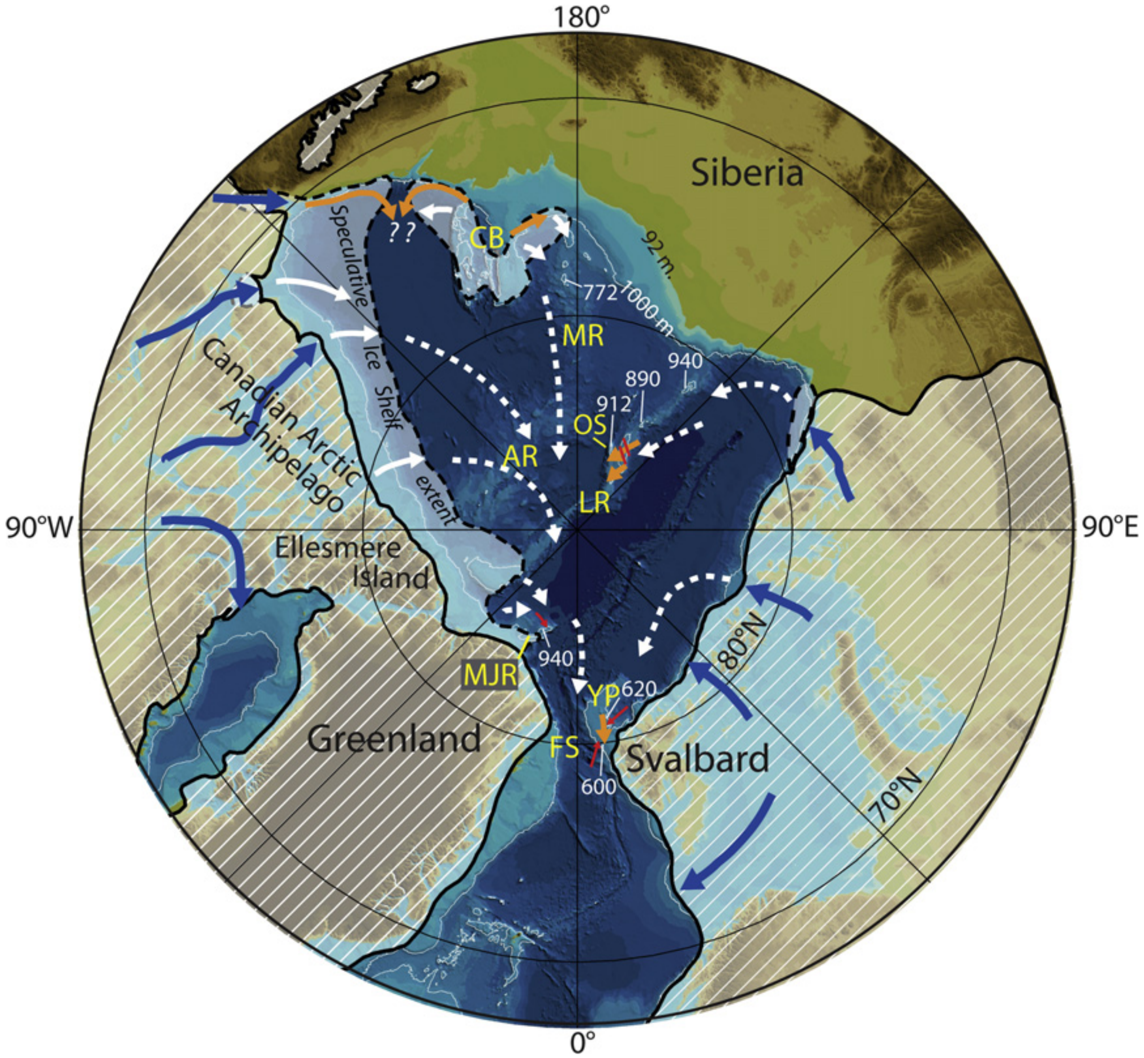
NCAR winter meeting 2016 - LIWG

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 Darby[i], Björn Eriksson[a], Daniela Hanslik[a], Benjamin Hell[a], Christian Marcussen[j], Emma Sellén[a], Åsa Wallin[a]

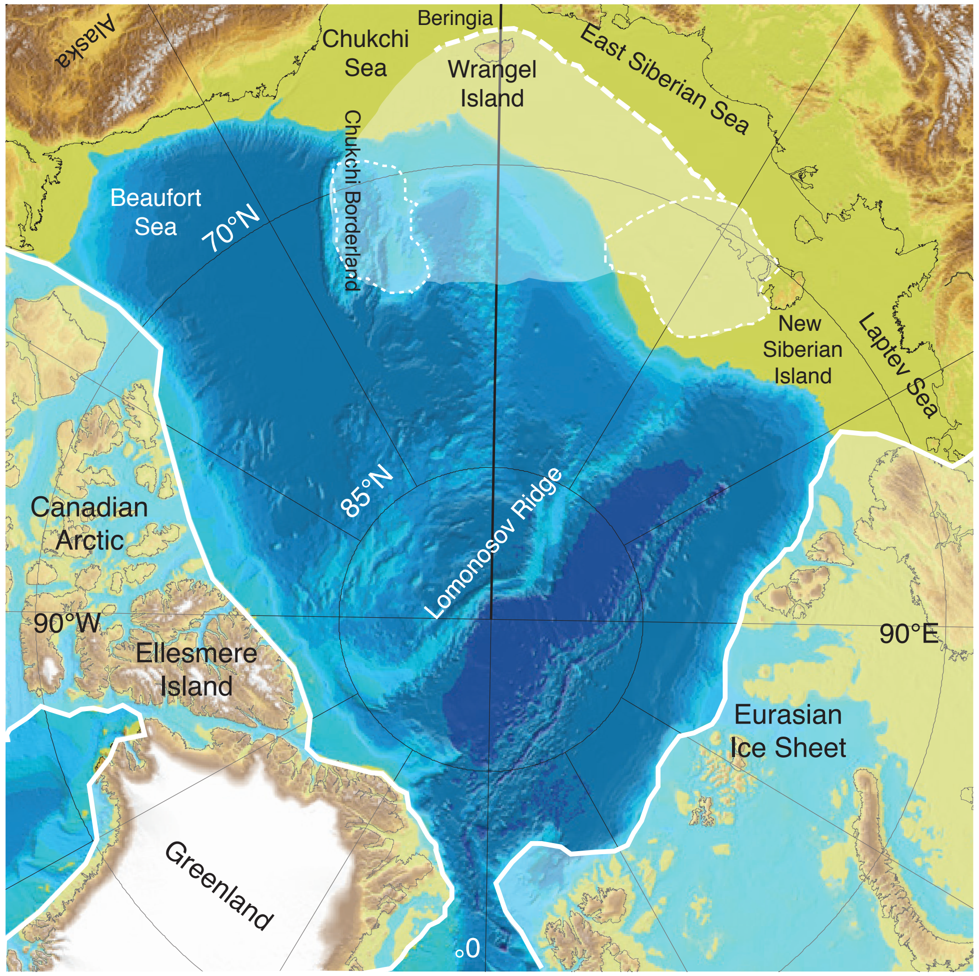
M. Jakobsson et al. / Quaternary Science Reviews 29 (2010) 3505–3517



Repeated Pleistocene glaciation of the East Siberian continental margin

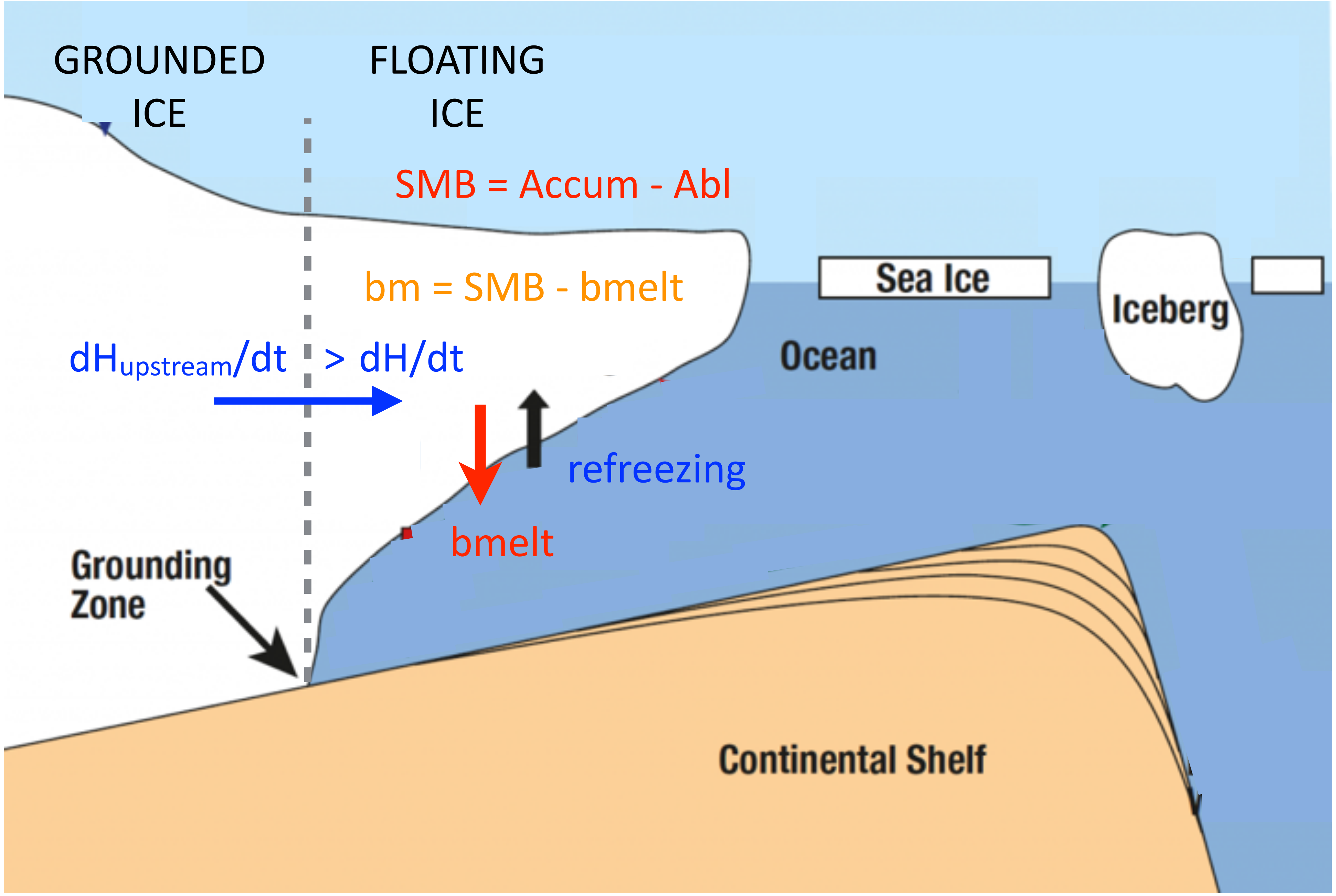
Nature Geoscience, 2013, vol. 6, no 10, p. 842-846

Frank Niessen[1]*, Jong Kuk Hong[2]*, Anne Hegewald[1], Jens Matthiessen[1], Rüdiger Stein[1], Hyoungjun Kim[2], Sookwan Kim[2,3], Laura Jensen[1], Wilfried Jokat[1], Seung-Il Nam[2] and Sung-Ho Kang[2]



Large uncertainties on ice shelves extent and timing

Choice of basal melting: ice shelf mass balance



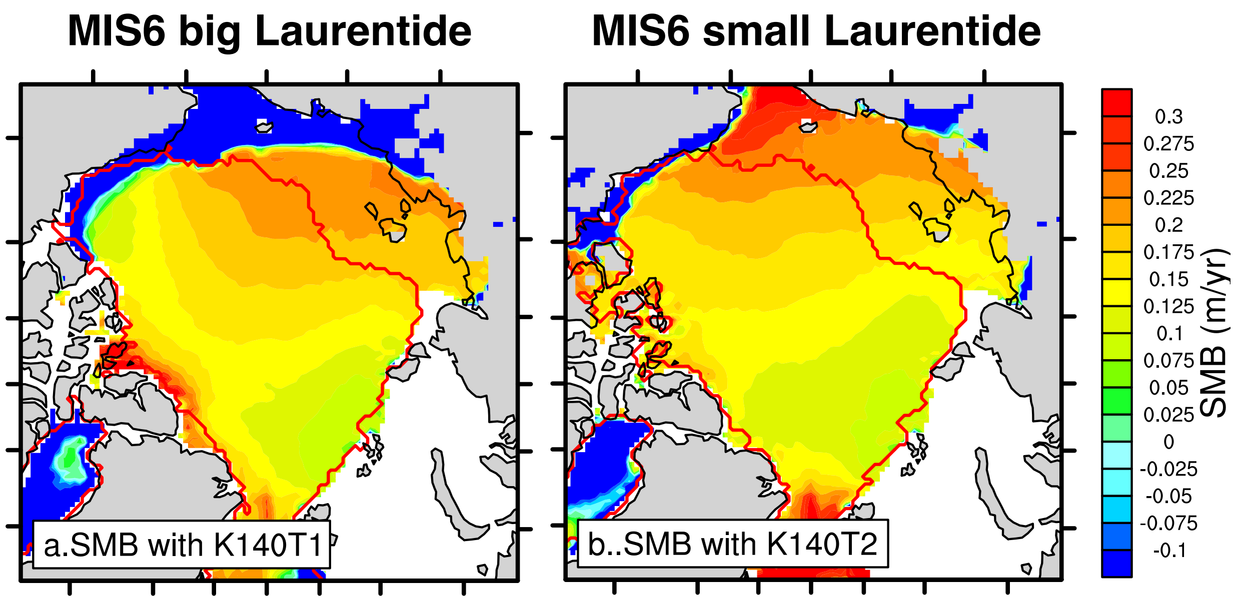
Calving if:

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

and/or

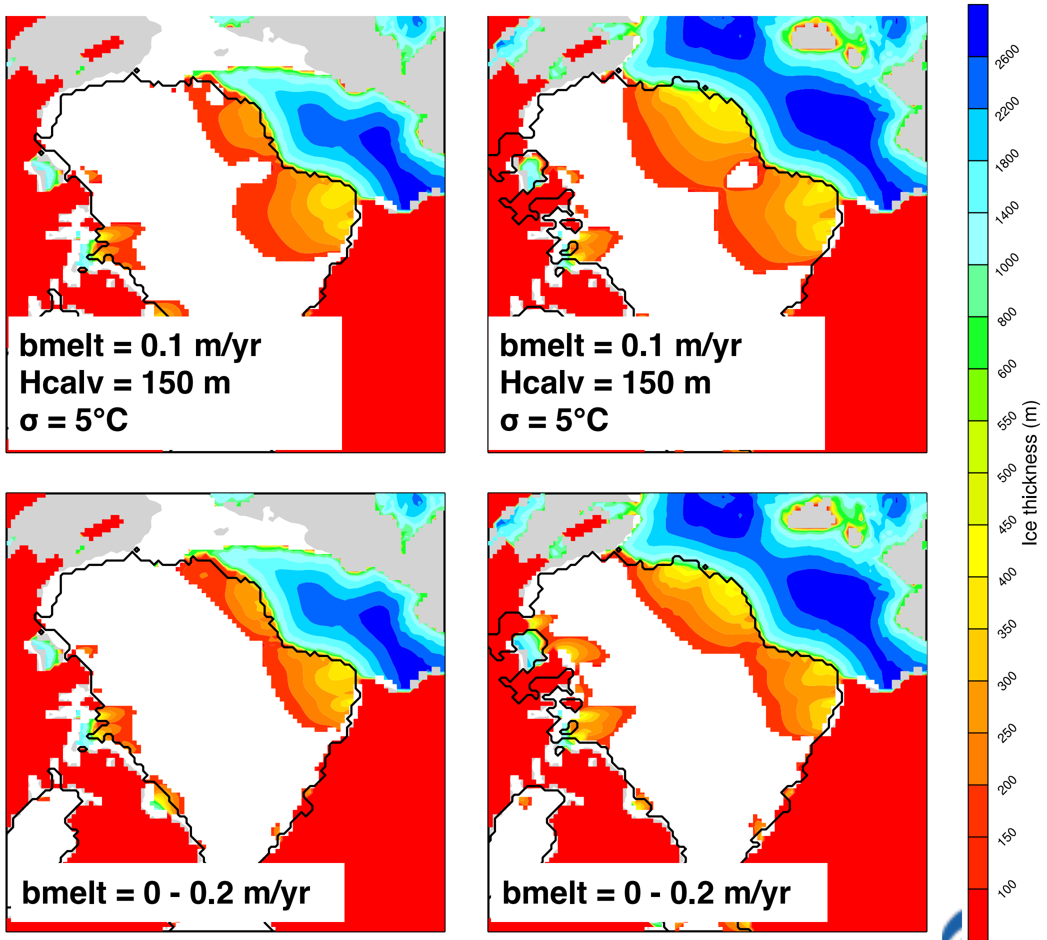
- ice shelf mass balance is negative

Choice of basal melting: ice shelf mass balance



To grow some ice shelves you need to consider:

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



BUT

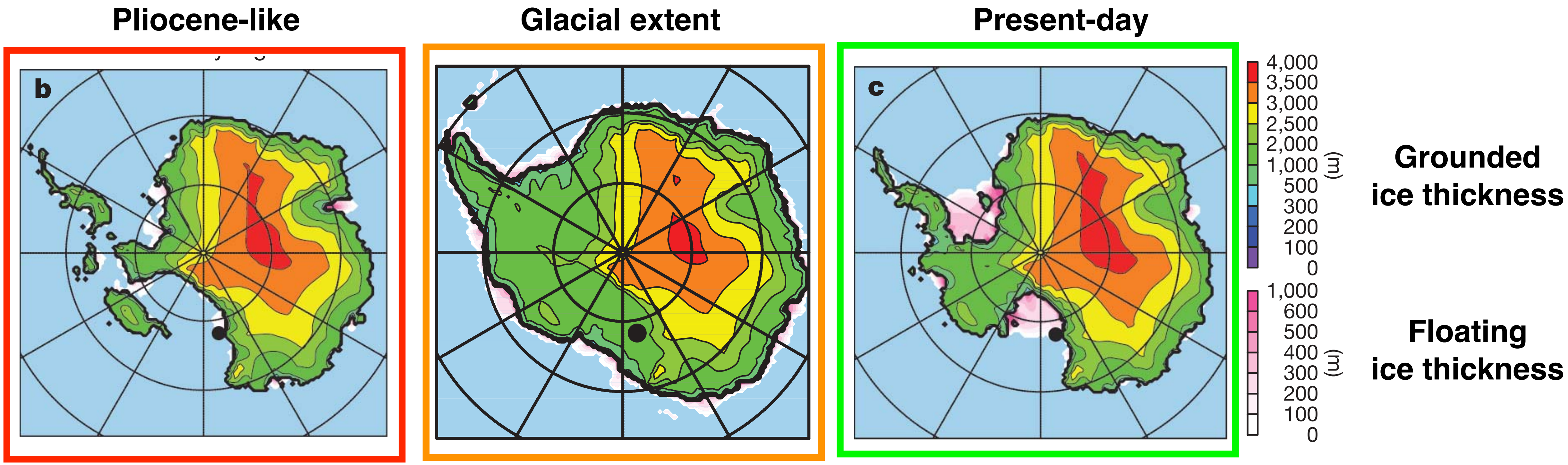
Now we are prescribing values to get the expected result!

Ice shelves in the past

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

David Pollard[1] & Robert M. DeConto[2]

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



Highly uncertain

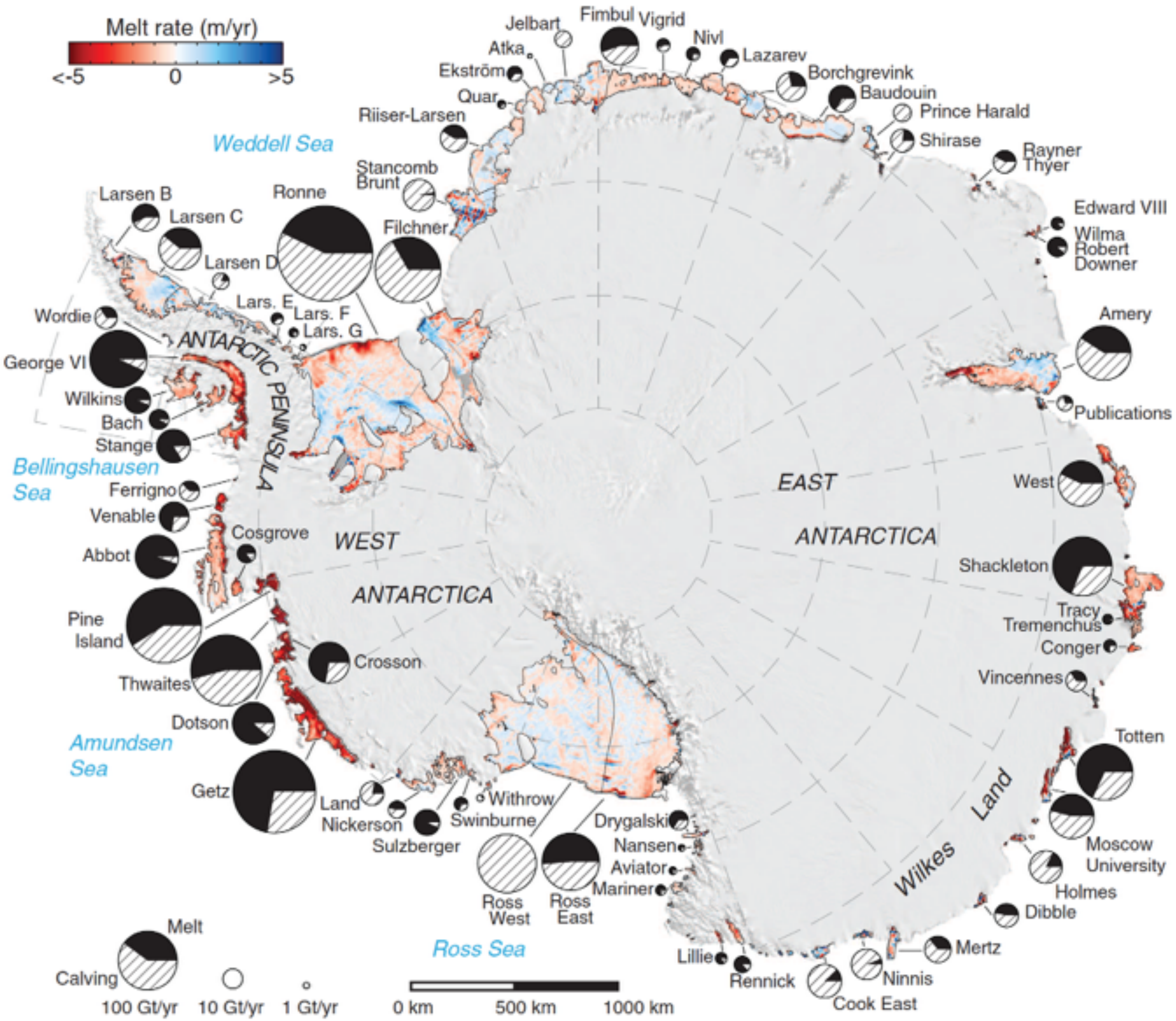
Moderately uncertain

Known

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:

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

+

Observations of ocean state

Parametrisations/ formulations of basal melting

Basal melting: the questions

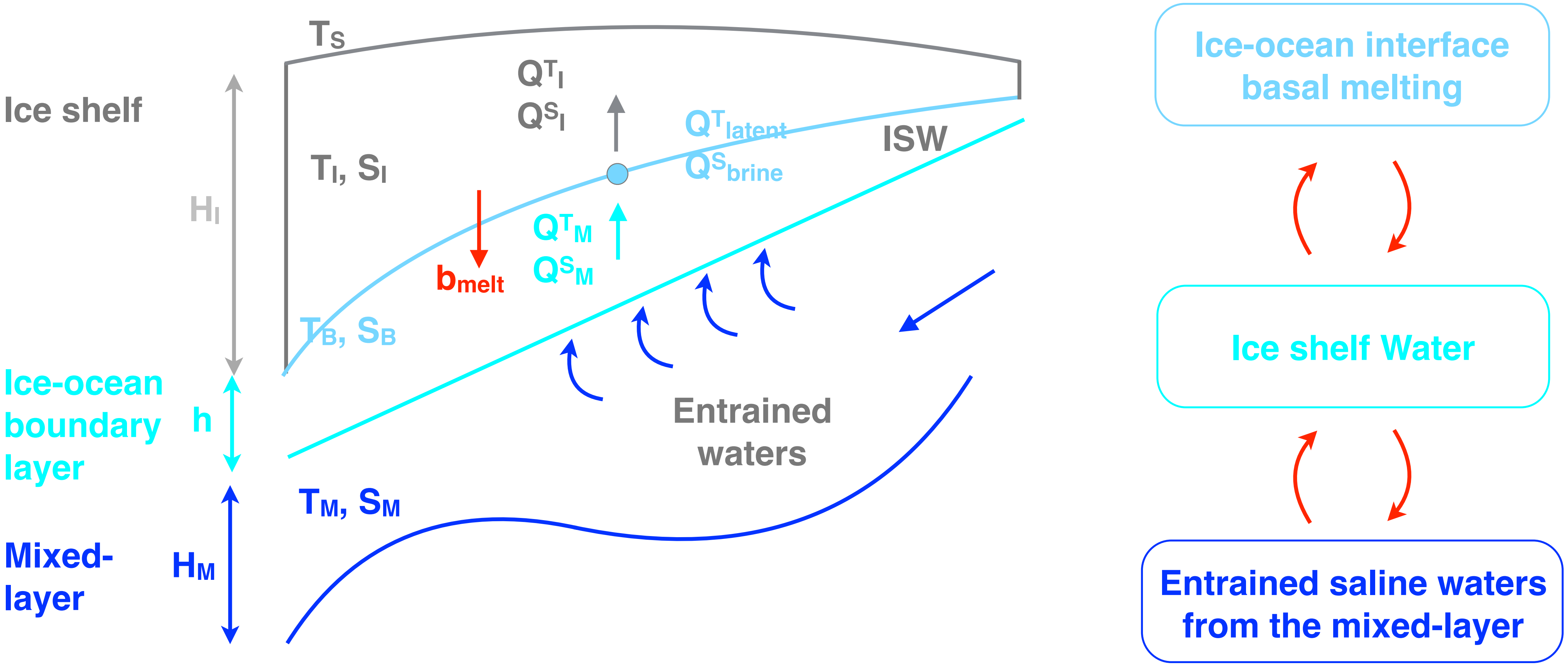
In the context of **stand alone ice-sheet*** modelling:

*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

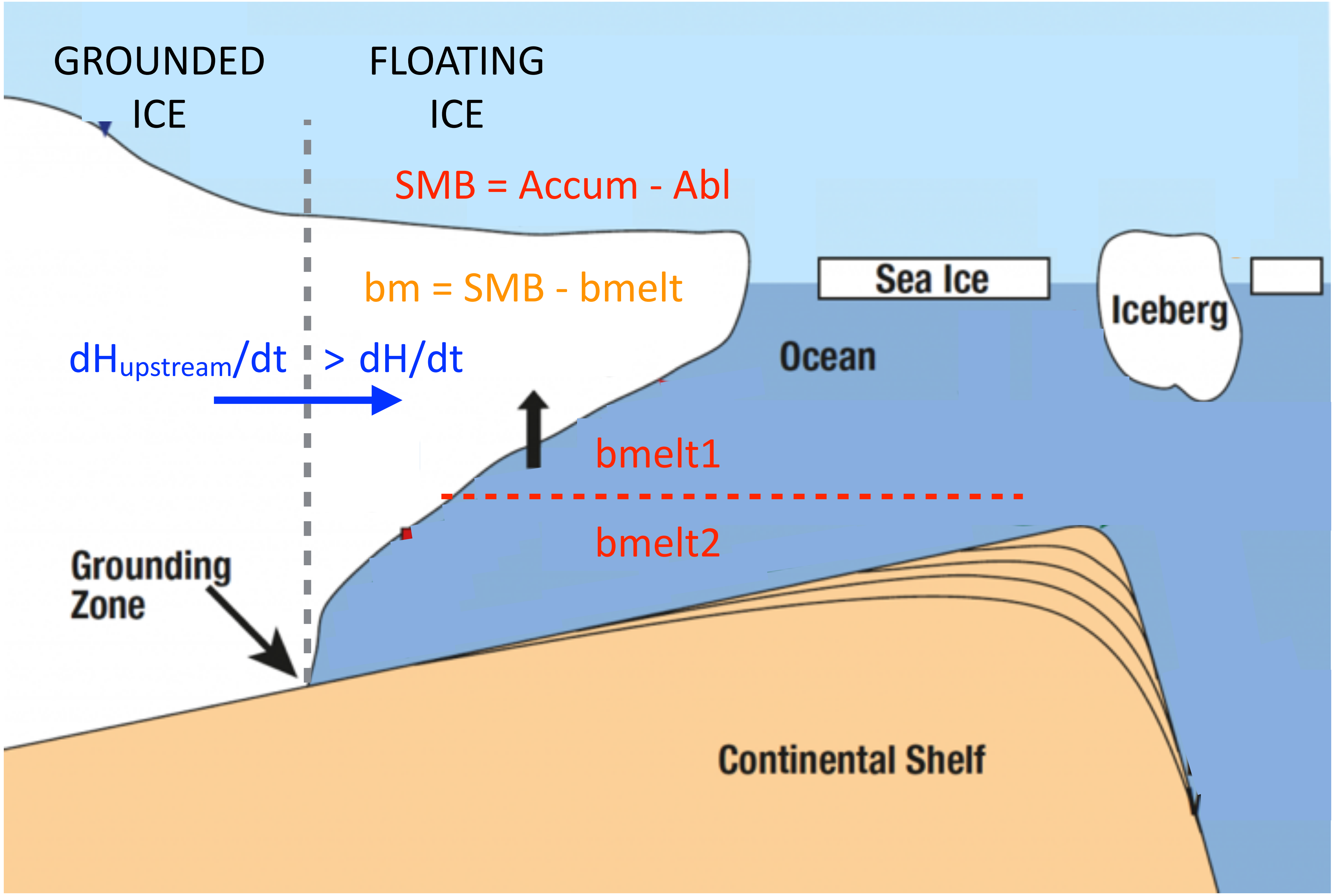
- Do parametrisations help providing some constraints?
- How to choose the basal melting formulation?

Basal melting: Ice shelf - ocean circulation cavity system



ISW: Ice Shelf Water

Basal melting: simplest parametrisation



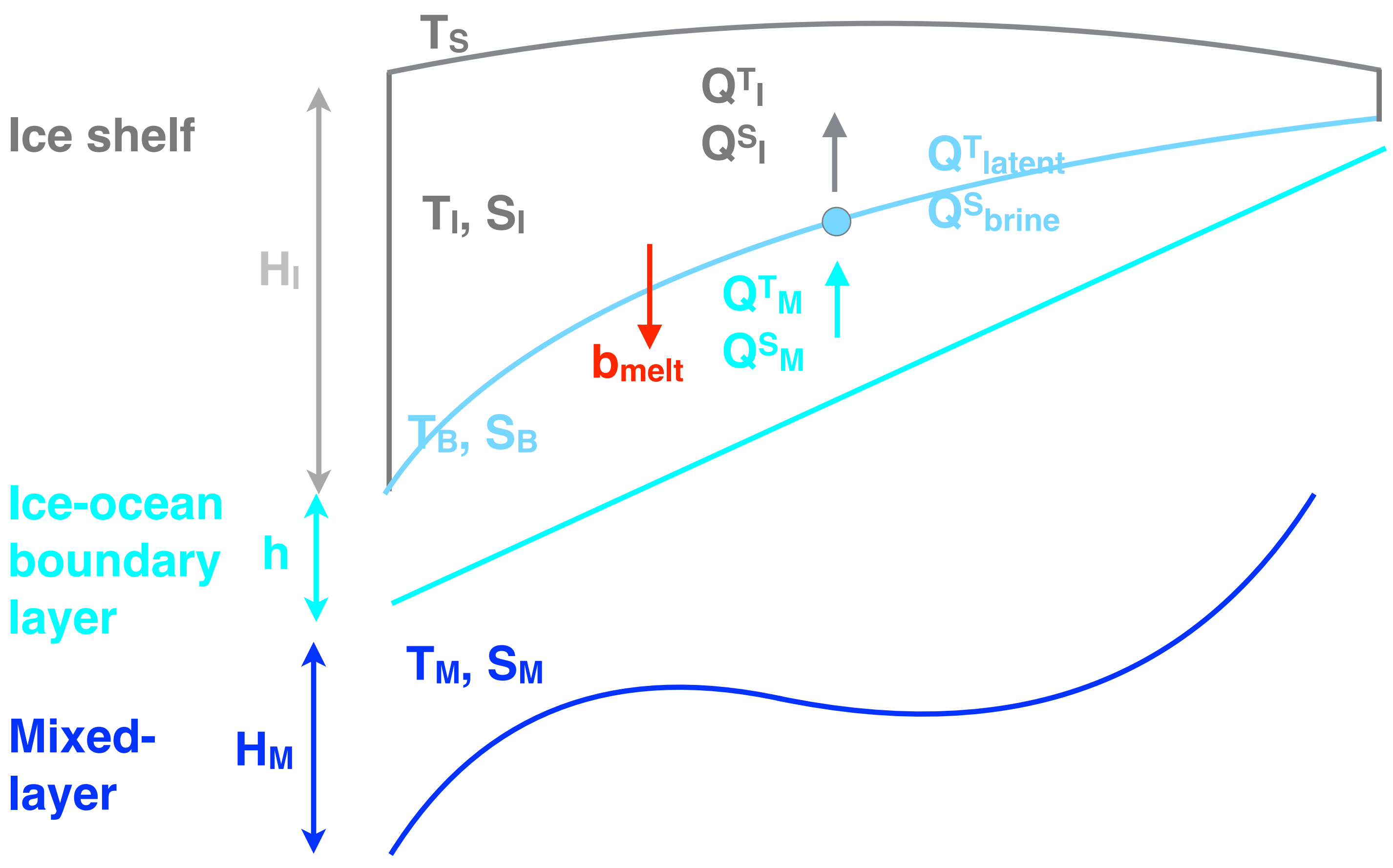
Limitations:

- ☐ 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



Exchange velocities:

γ_T

γ_S

both depend on the friction velocity *u**

$$u* = c_d U_M^2$$

drag coeff.

ML velocity

Holland and Jenkins (1999):

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

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

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

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

$Q_I^S = 0$ No salt diffusion within the ice shelf

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

↓

salinity exchange velocity

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

Basal melting: examples

Holland and Jenkins (1999): Three equations formulations

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

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

no plume

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

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

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

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

Fmelt = 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)

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

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

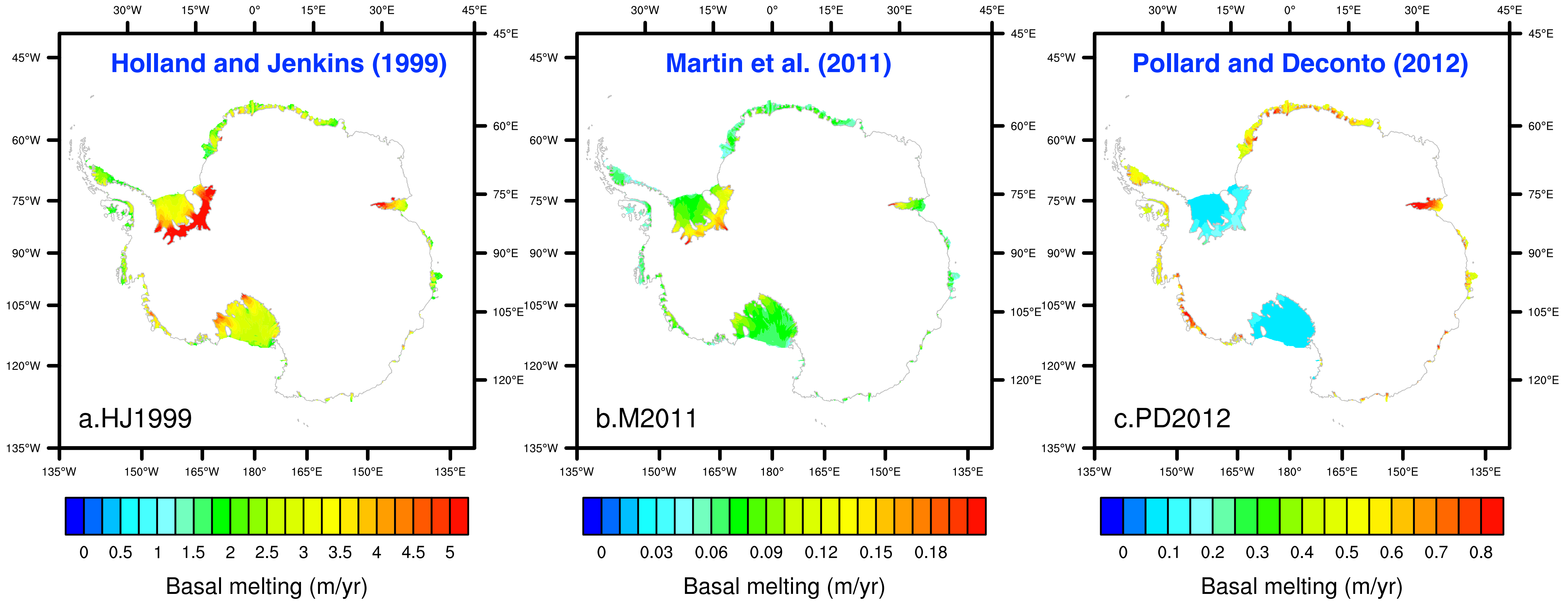
$$K' = K w_a + (-1.7)(1 - w_a)$$

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

A_a = subtended arc-to-ocean angle

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

Basal melting: Present-day Antarctica



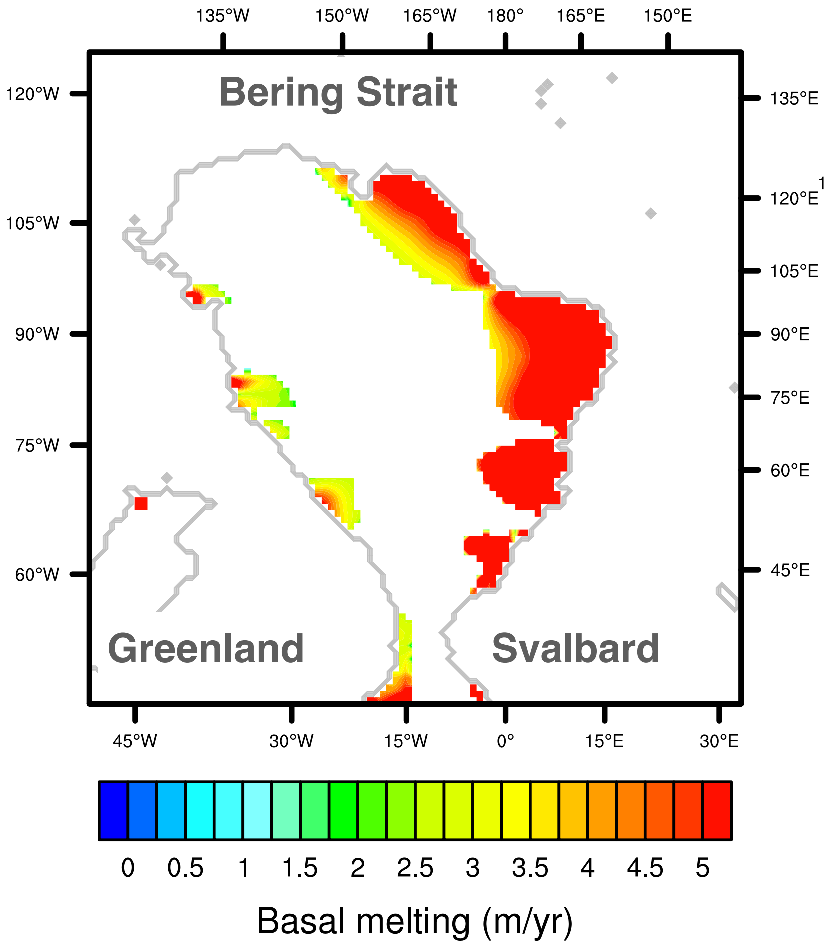
One order magnitude difference between Martin et al. (2011) and the two other methods

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

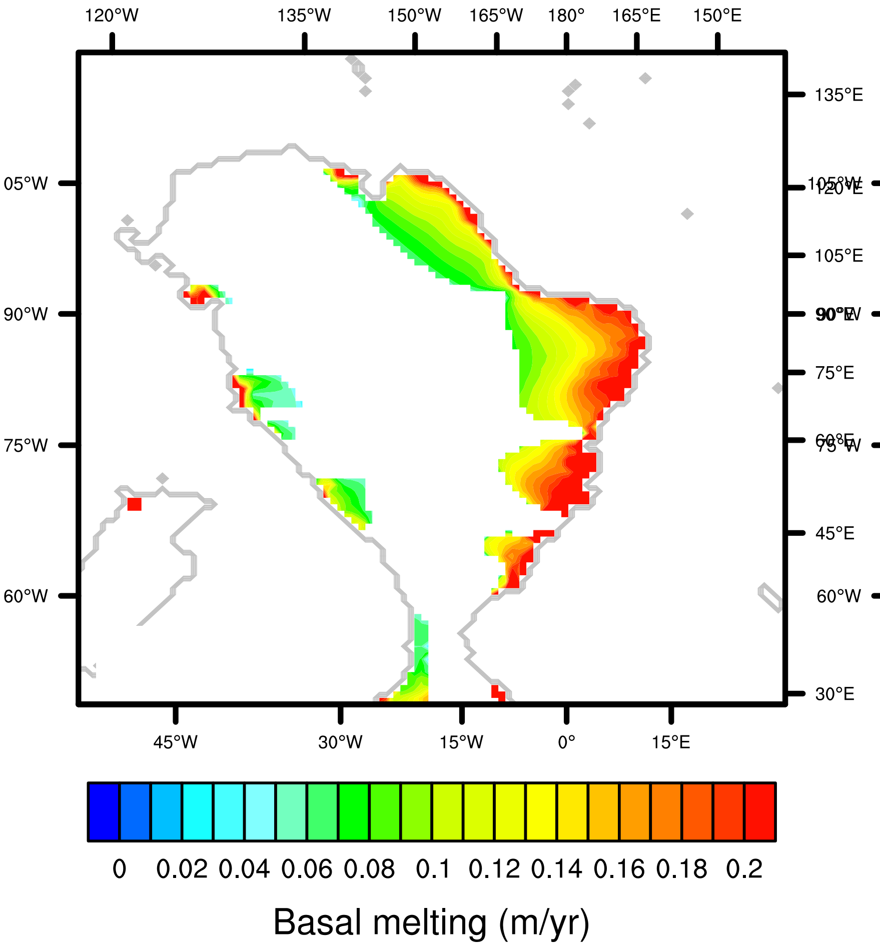
Note that the color scales are different

Basal melting: Penultimate glaciation in Arctic

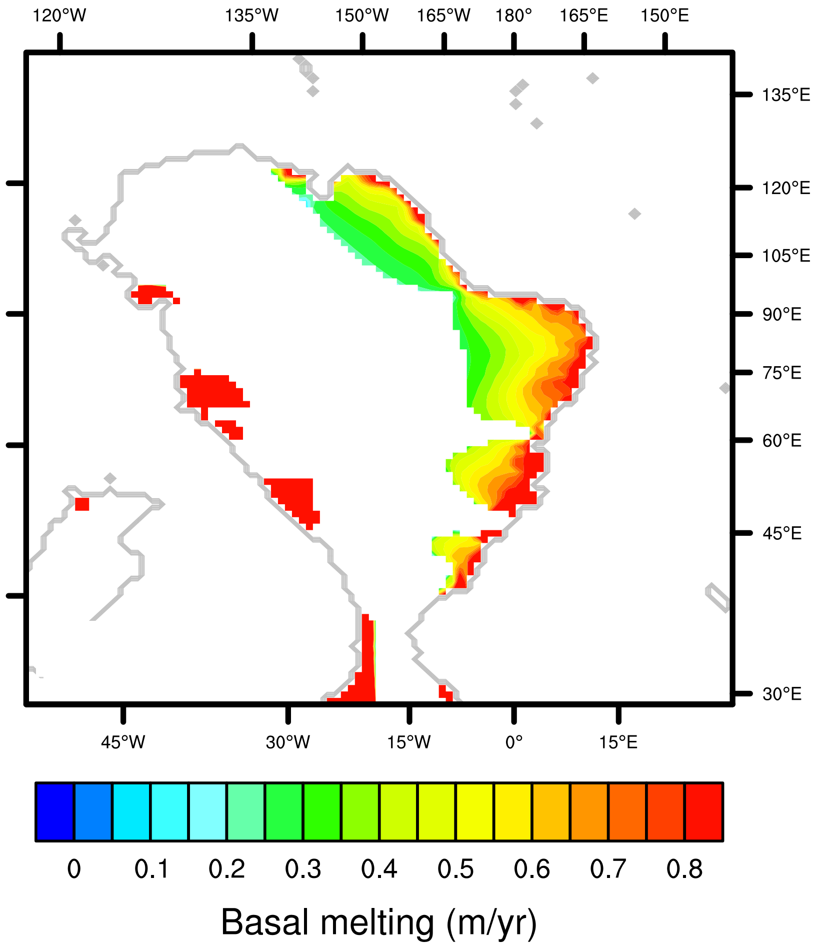
Holland and Jenkins (1999)



Martin et al. (2011)



Pollard and Deconto (2012)

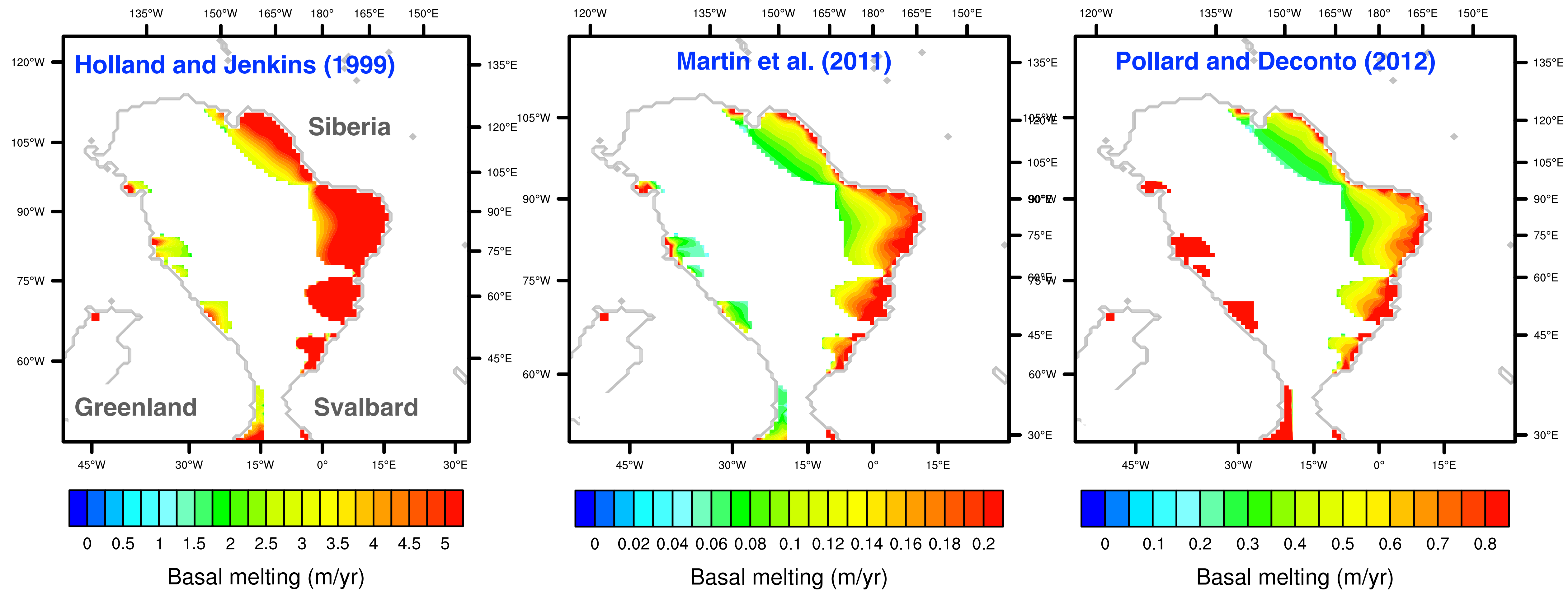


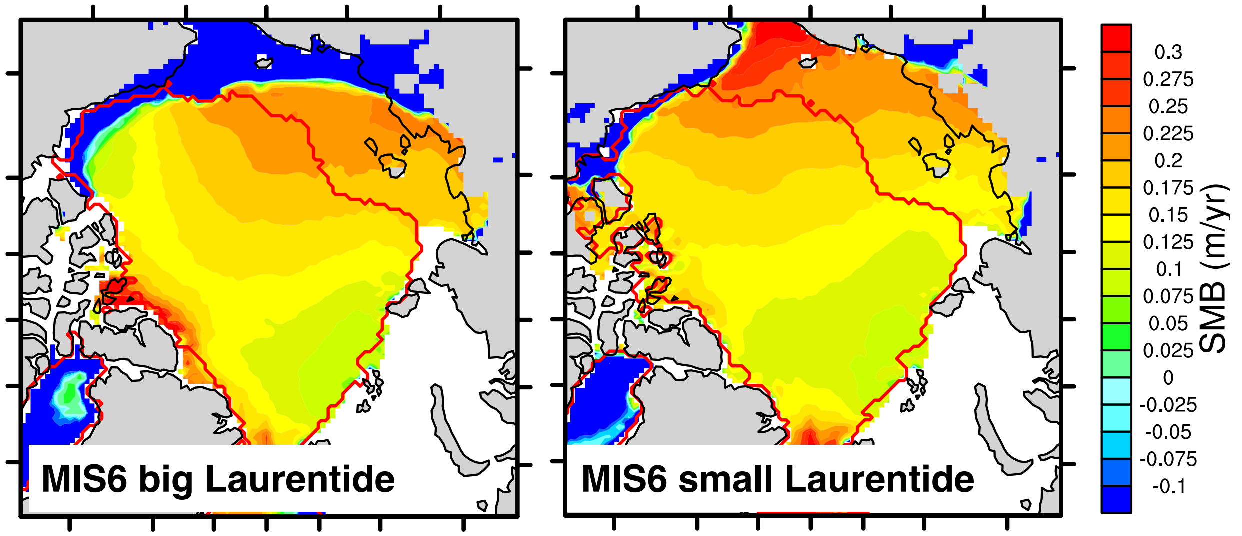
Martin et al. (2011) seems more reasonable than the others

Forced with LGM ocean temperatures from Brady et al. (2013)

Note that the color scales are different

Basal melting: Last Glacial Maximum Arctic





To grow ice shelves:

basal melting < SMB (~0.15 m/yr)

Forced with MIS6 ocean temperatures from Colleoni et al. (2016)

Note that the color scales are different

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?