The Greenland Ice Sheet-ocean interaction in the past two glacial cycles

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PalMA
Paleoclimate Modeling and Analysis

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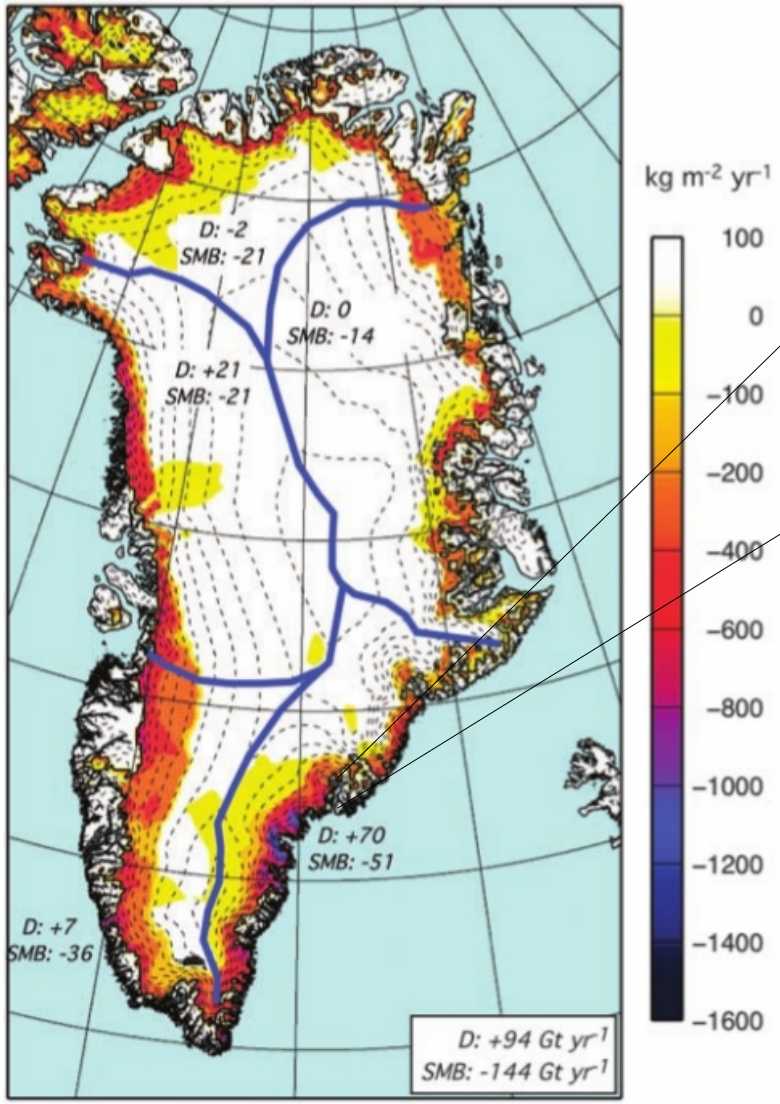
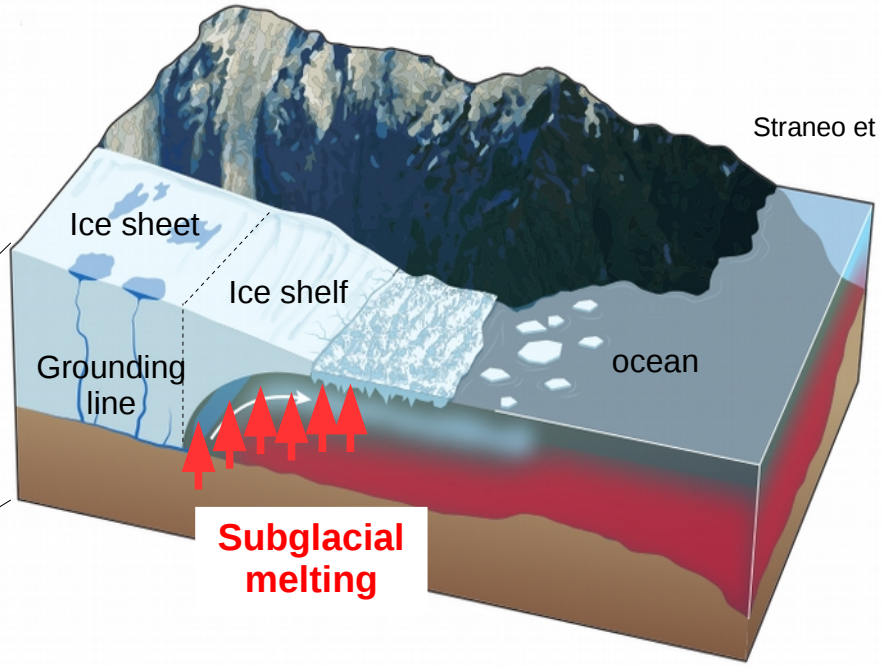
Recent GrIS mass loss

Present GrIS mass balance



Van Den Broeke et al., 2009

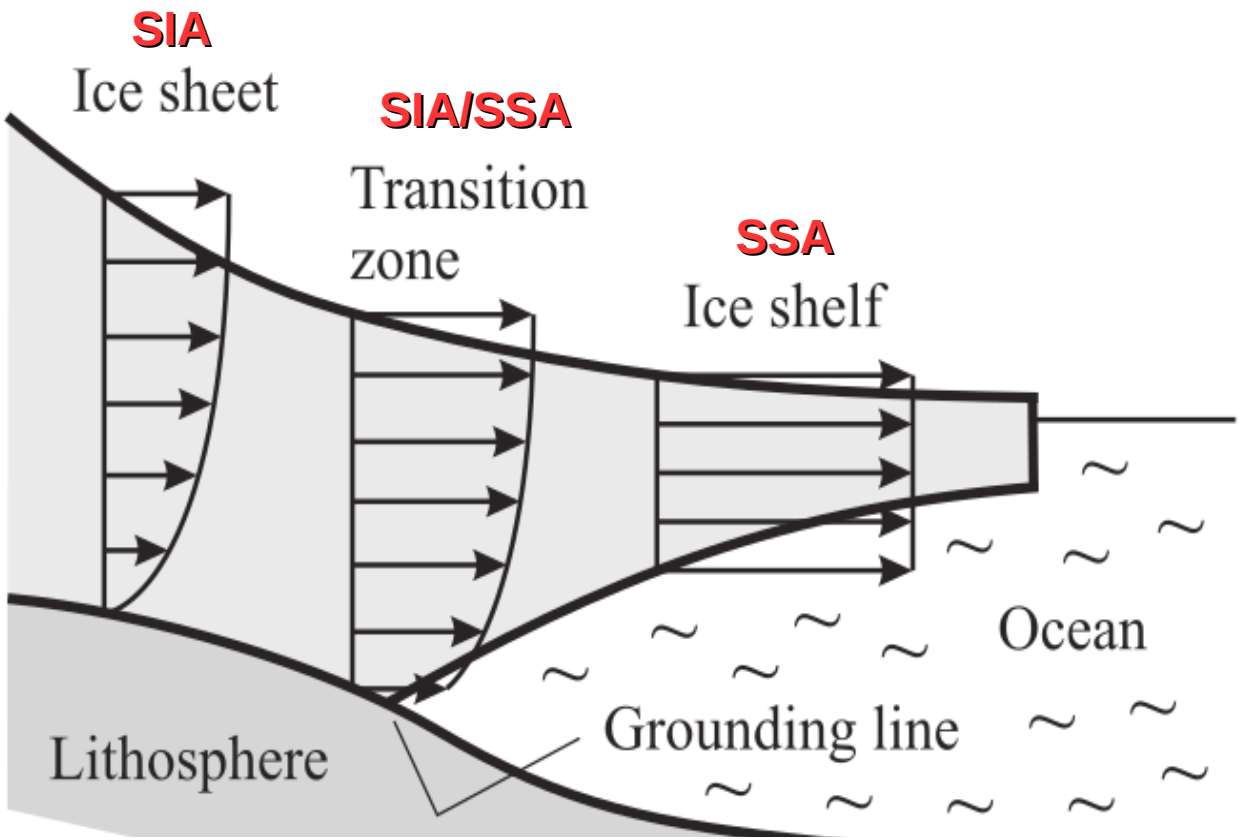


Straneo et al., 2013

*How did the **oceanic forcing** impact the evolution of the past GrIS?*

Yelmo ice sheet model

- 3D hybrid thermomechanical ice sheet – ice shelf model (based on GRISLI) Ritz et al., 2001
- SIA (grounded ice) and SSA (ice shelves)



Greve and Blatter, 2009

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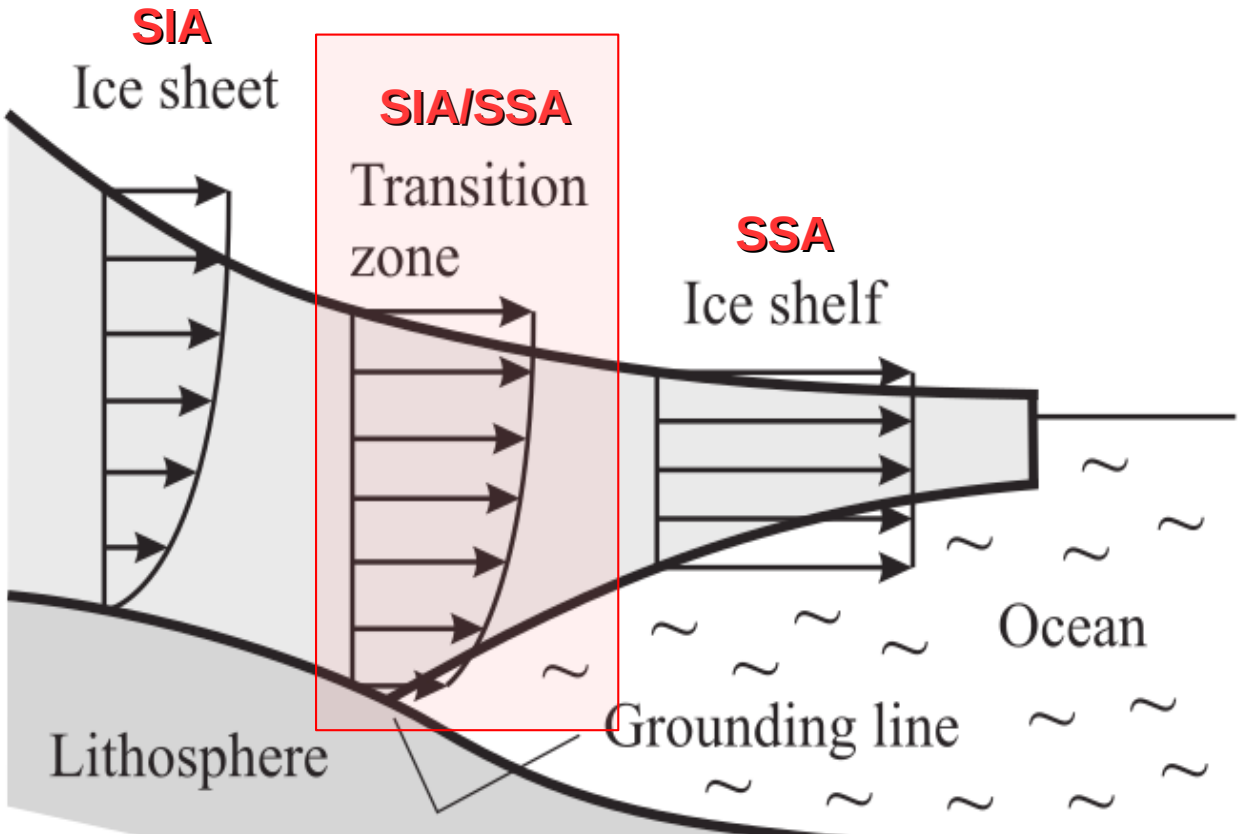
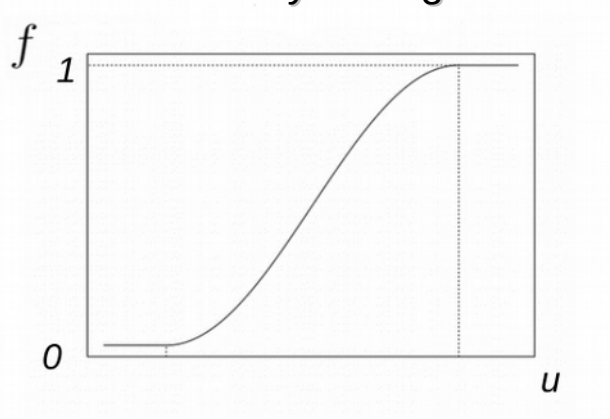


Greve and Blatter, 2009

Velocity mixing



$$\vec{u} = (1 - f)\,\vec{u}_{SIA} + f\,\vec{u}_{SSA}$$

Bueler and Brown, 2009

Paleoclimatic forcings

- Atmospheric forcing evolution

$$T_{atm} = T_{ref} + \Delta T_{atm}$$

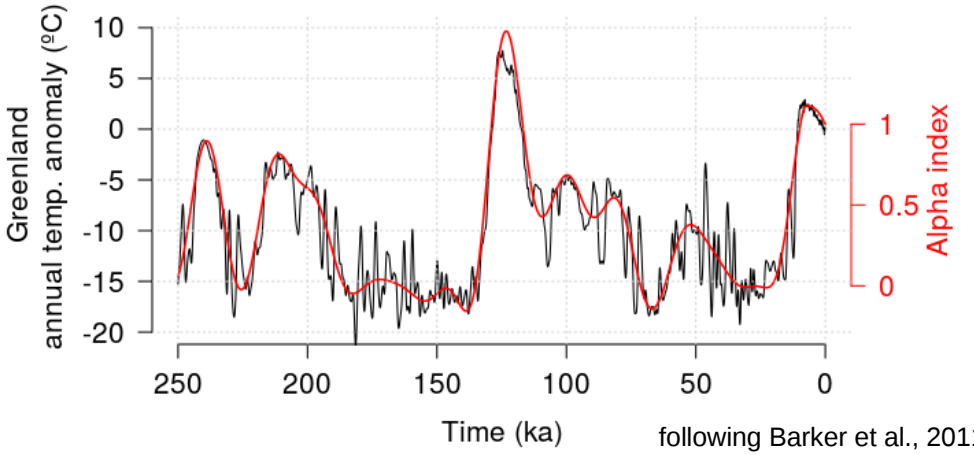
Similar procedure for precipitation

$$\Delta T_{atm} = (1 - \alpha)\,(T_{LGM,atm} - T_{PD,atm})$$

from Climber 3α

Montoya and Levermann, 2008

Applied to the whole GrIS



following Barker et al., 2011

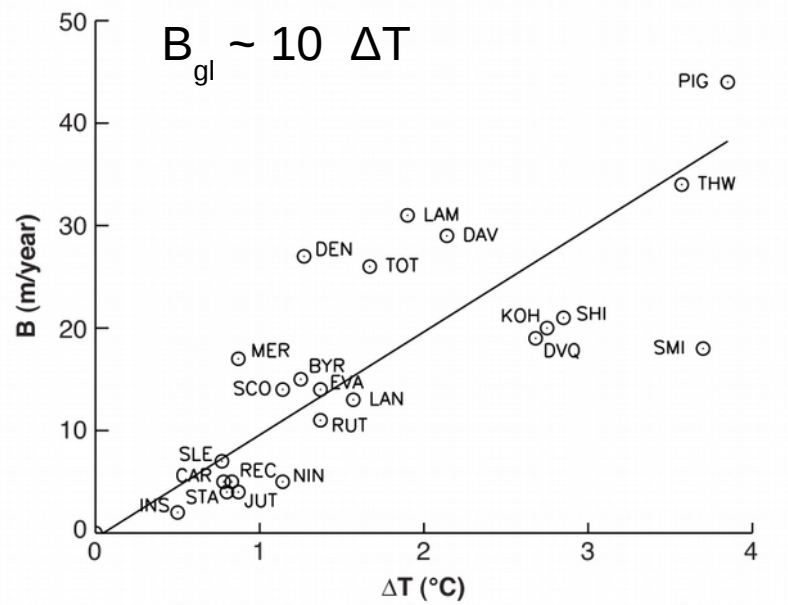
- Oceanic forcing evolution

$$B_{gl} = B_{ref} + \kappa\ \Delta T_{ocn}$$

$$\Delta T_{ocn} = (1 - \alpha)\,(T_{LGM,ocn} - T_{PD,ocn})$$

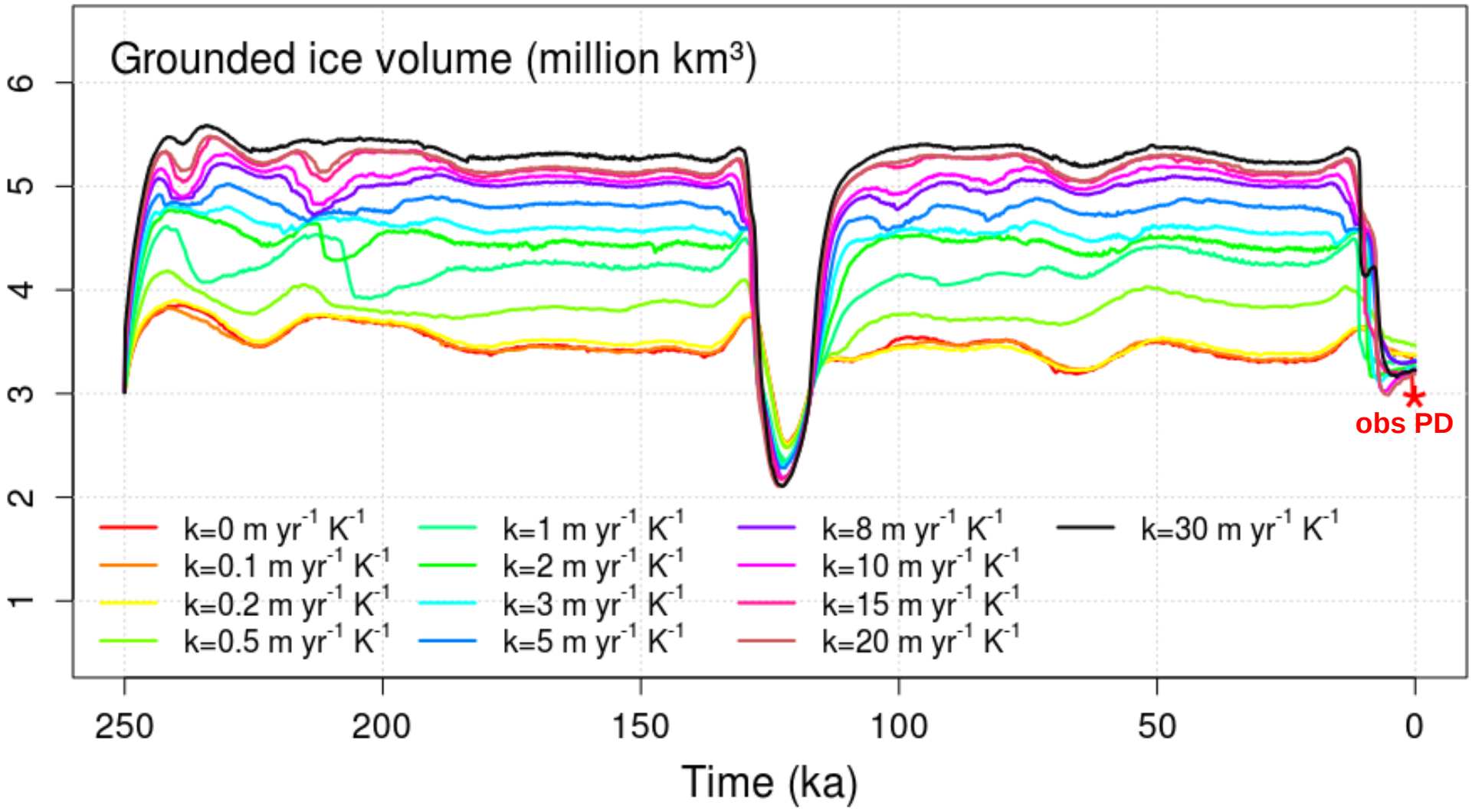
Spatially homogeneous

Boundary condition at the marine ice sheets

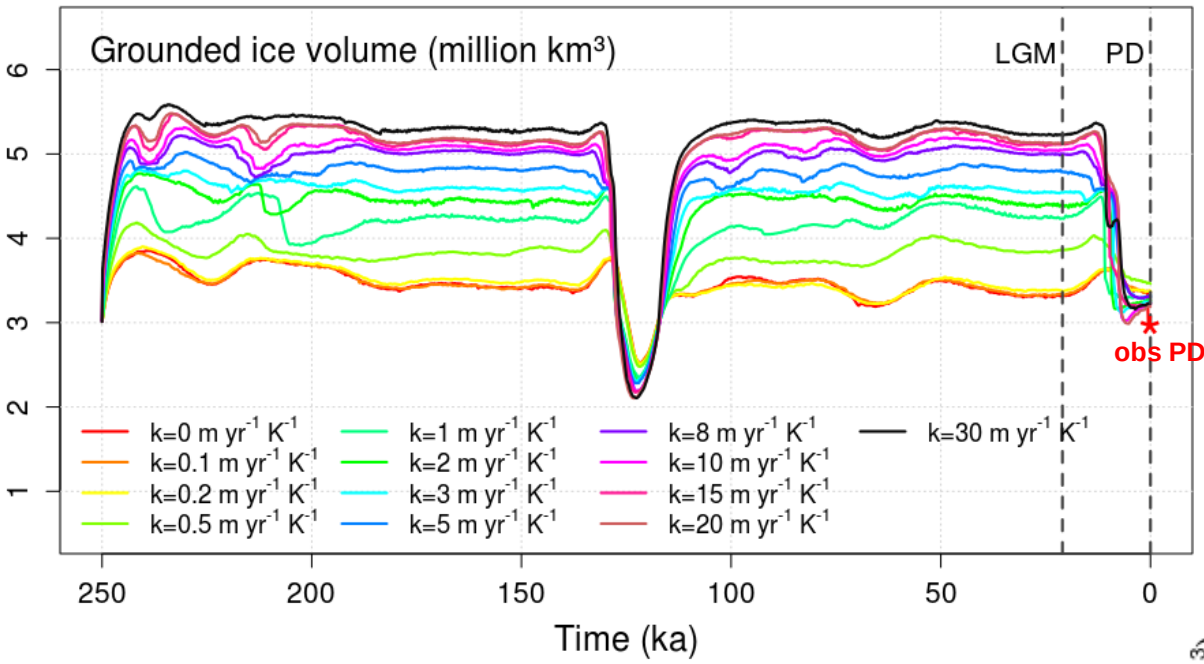


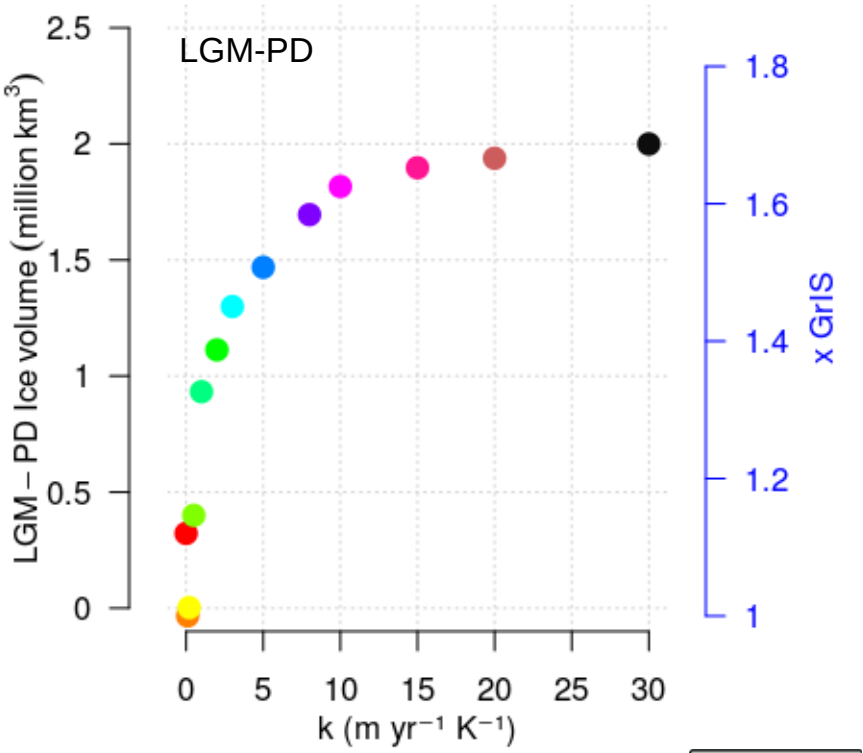
Rignot et al., 2002

Modelled past GrIS evolution



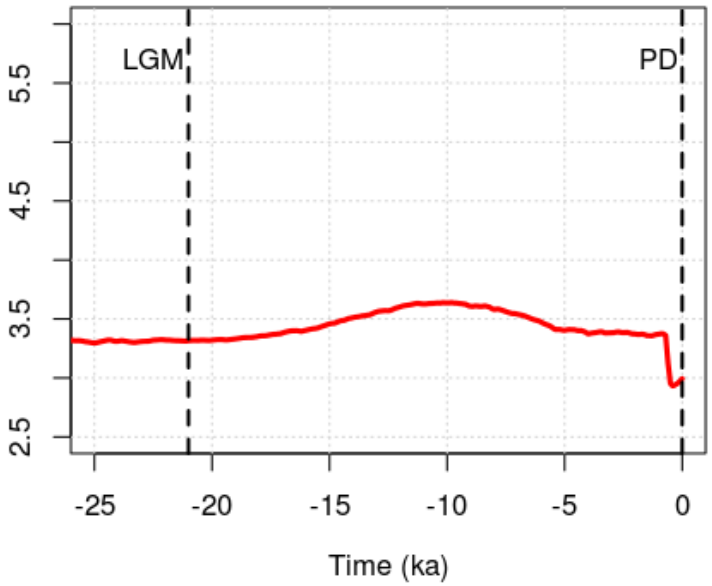
Modelled past GrIS evolution



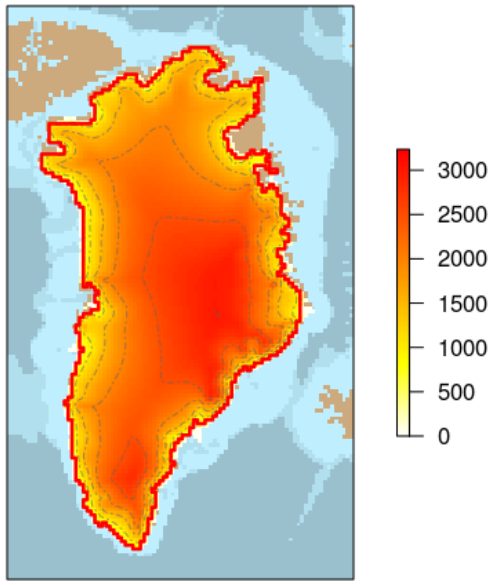


k = 0 m yr^{-1} K^{-1}

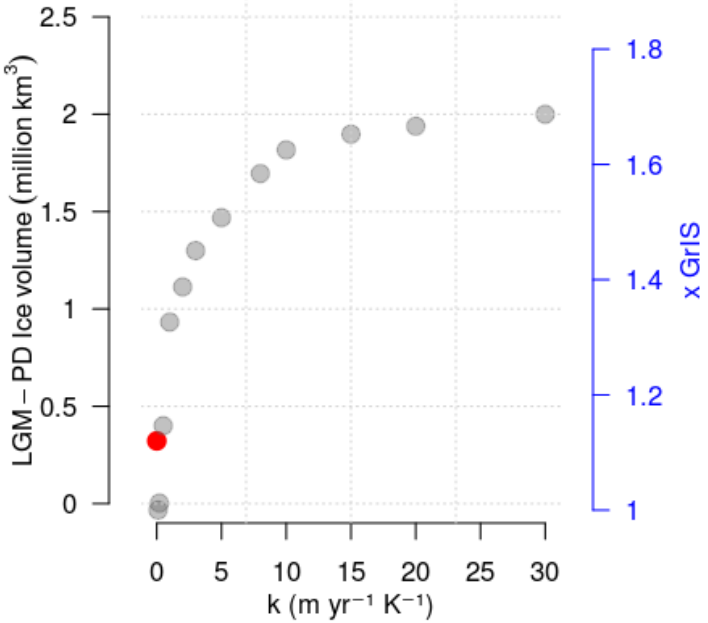
Grounded ice volume (million km^3)



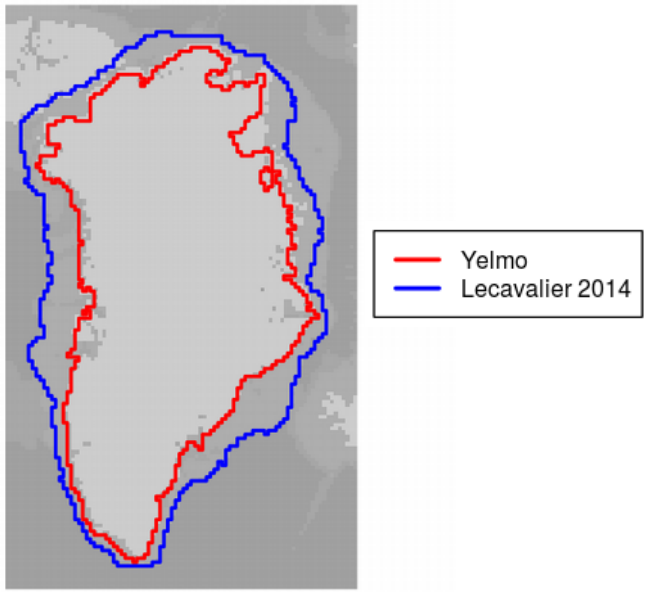
LGM Surface elevation (m)



LGM-PD ice volume

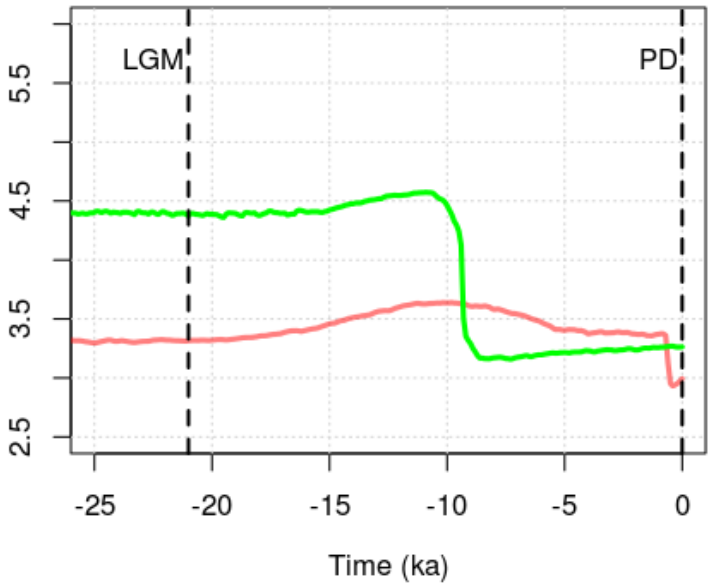


LGM Grounding Line

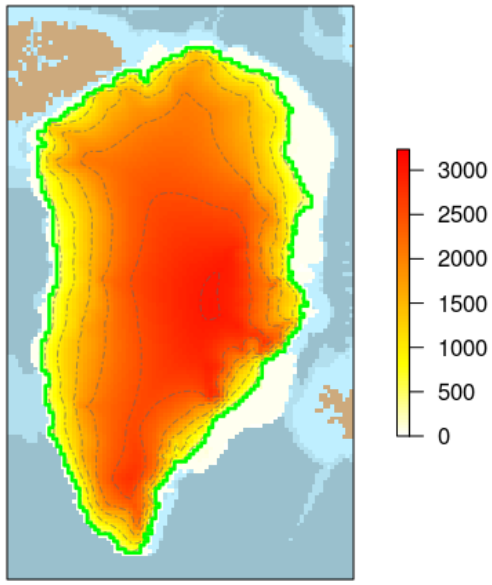


k = 2 m yr^{-1} K^{-1}

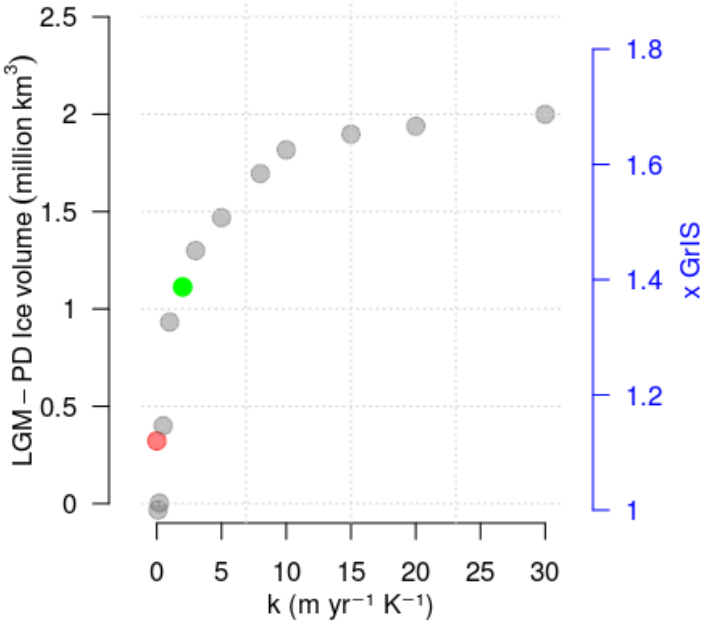
Grounded ice volume (million km^3)



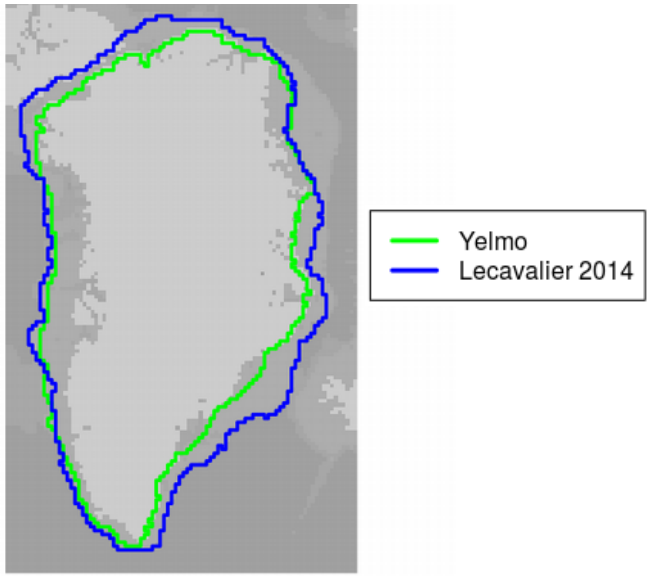
LGM Surface elevation (m)



LGM-PD ice volume

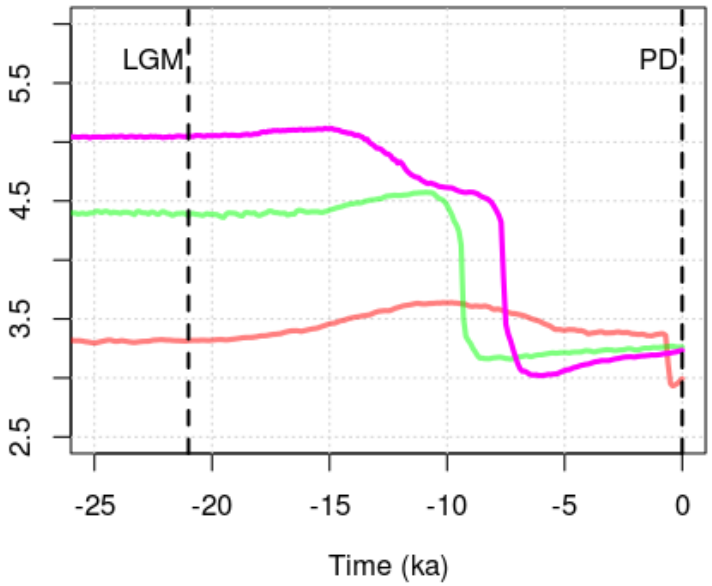


LGM Grounding Line

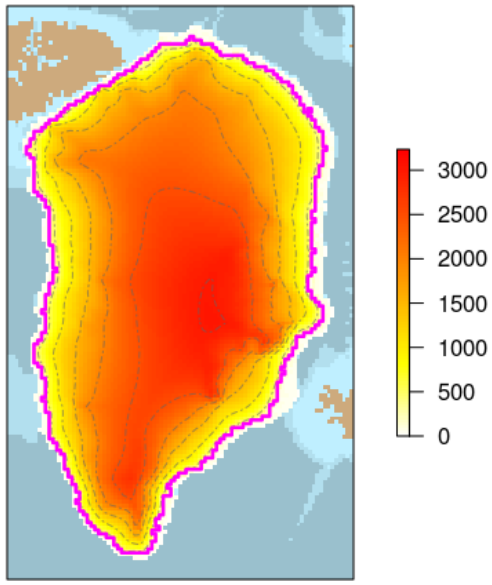


k = 10 m yr^{-1} K^{-1}

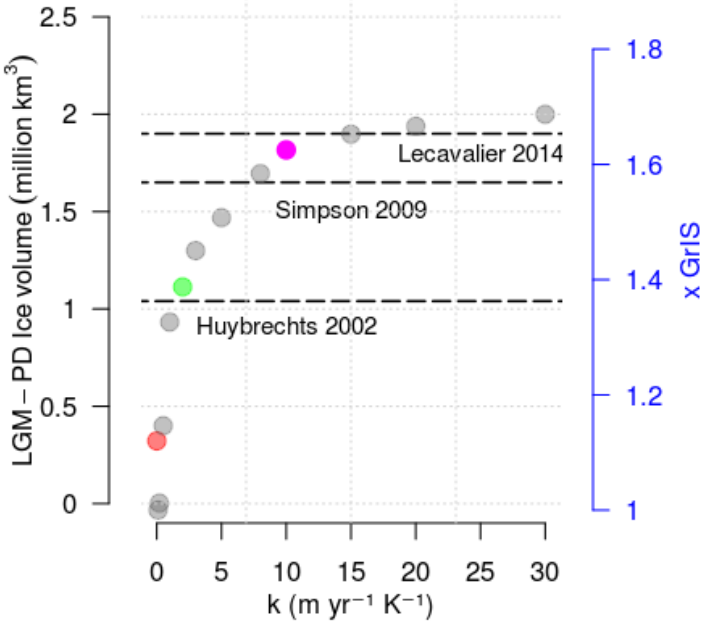
Grounded ice volume (million km^3)



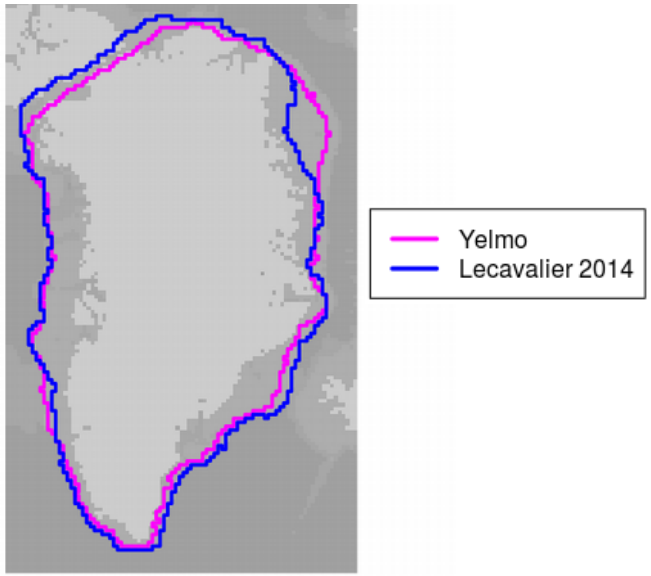
LGM Surface elevation (m)



LGM-PD ice volume



LGM Grounding Line



Conclusions

- *CAVEAT*: Sub-grid grounding line treatment
- Oceanic sensitivity of the past GrIS is investigated for the first time as *active forcing*
- Oceanic forcing is *crucial* in the evolution of the GrIS through the cycles
- Not only it drives the grounding line retreat in warm periods, but also the *grounding line advance (and ice growth) during the glacials*
- Grounding line is free to reach the continental shelf only from a high oceanic sensitivity

Thanks for your attention

From Beckmann and Goosse 2003

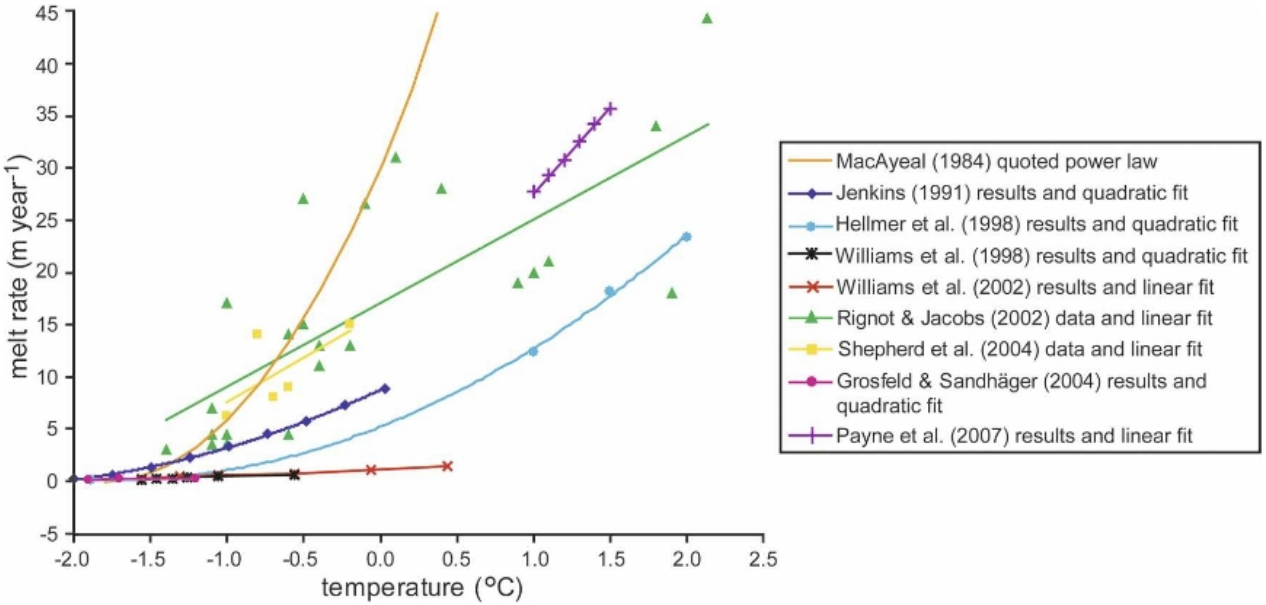
$$B_{gl} = \kappa \left(T_{ocn} - T_{fp} \right)$$

$$B_{gl} = \kappa \left(\left(T_{clim,ocn} + \Delta T_{ocn} \right) - T_{fp} \right)$$
$$\Delta T_{ocn} = (1 - \alpha) \left(T_{LGM,ocn} - T_{PD,ocn} \right)$$

$$B_{gl} = \kappa \left(T_{clim,ocn} - T_{fp} \right) + \kappa \, \Delta T_{ocn}$$

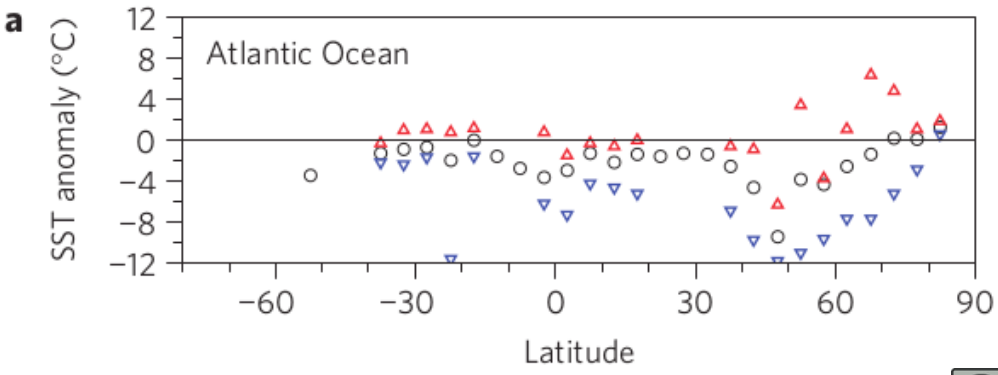
$$\begin{cases} B_{gl} = B_{ref} + \kappa \, \Delta T_{ocn} \\ B_{shelf} = \gamma \, B_{gl} \end{cases}$$

B_{ref} = 1 m/yr
k = (0,30) m/yr/K
$T_{LGM} - T_{PD}$ = - 3K



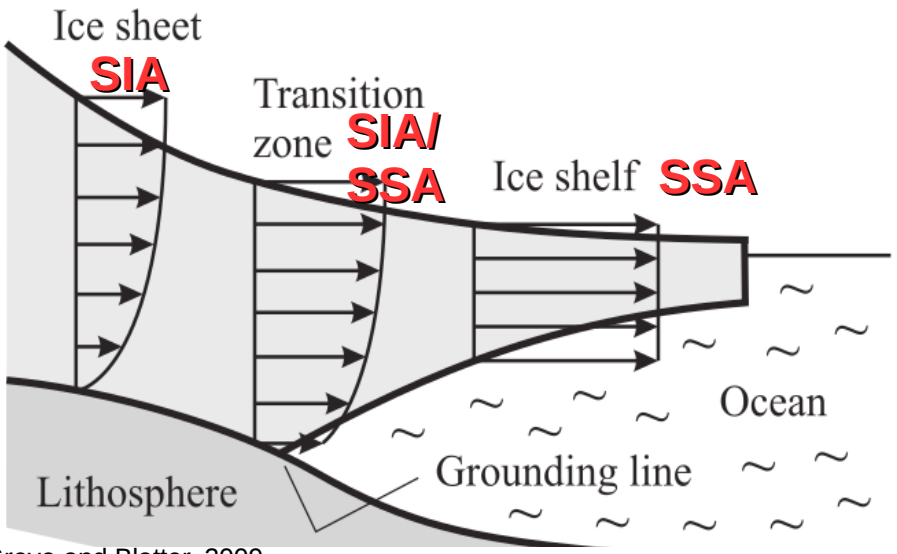
P.R. Holland and A. Jenkins, *2008*

MARGO Project members, 2009



Yelmo ice model

3D hybrid thermomecanical model



Greve and Blatter, 2009

Dragging laws

SIA → Ice sheet

$$\vec{u}_b = 0$$

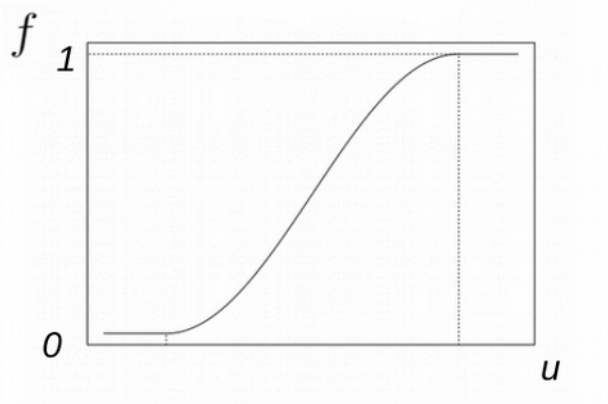
SSA → Ice stream / Ice shelf

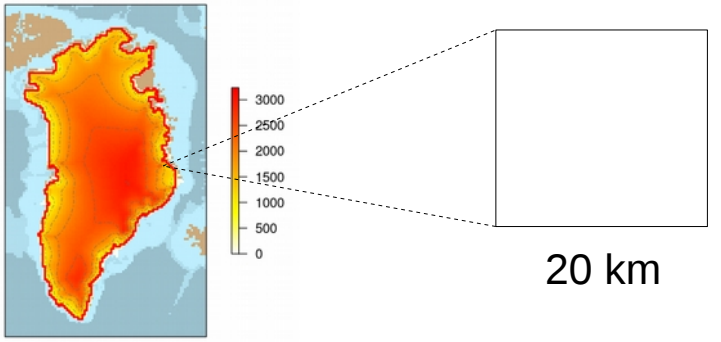
$$\vec{\tau}_b = -\beta\ \vec{u}_b$$

$$\beta = c_f\ N_{eff}$$

$$\vec{\tau}_b = 0$$

Velocity mixing



$$\vec{u} = (1 - f)\ \vec{u}_{SIA} + f\ \vec{u}_{SSA}$$

Spatial resolution