Antarctic ice-sheet interactions during the last Deglaciation

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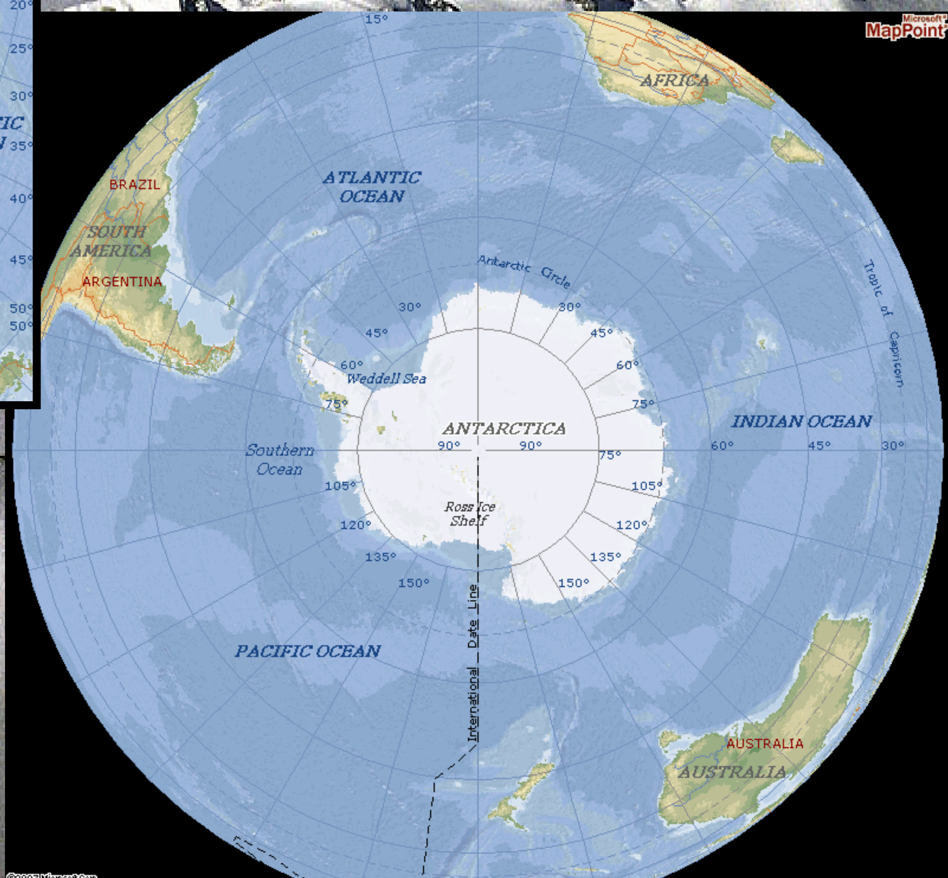
PhD studies in “*Laboratoire des Sciences du Climat et de l’Environnement*” (LSCE, Saclay), 2003-2007

IPCC 2007 AR4

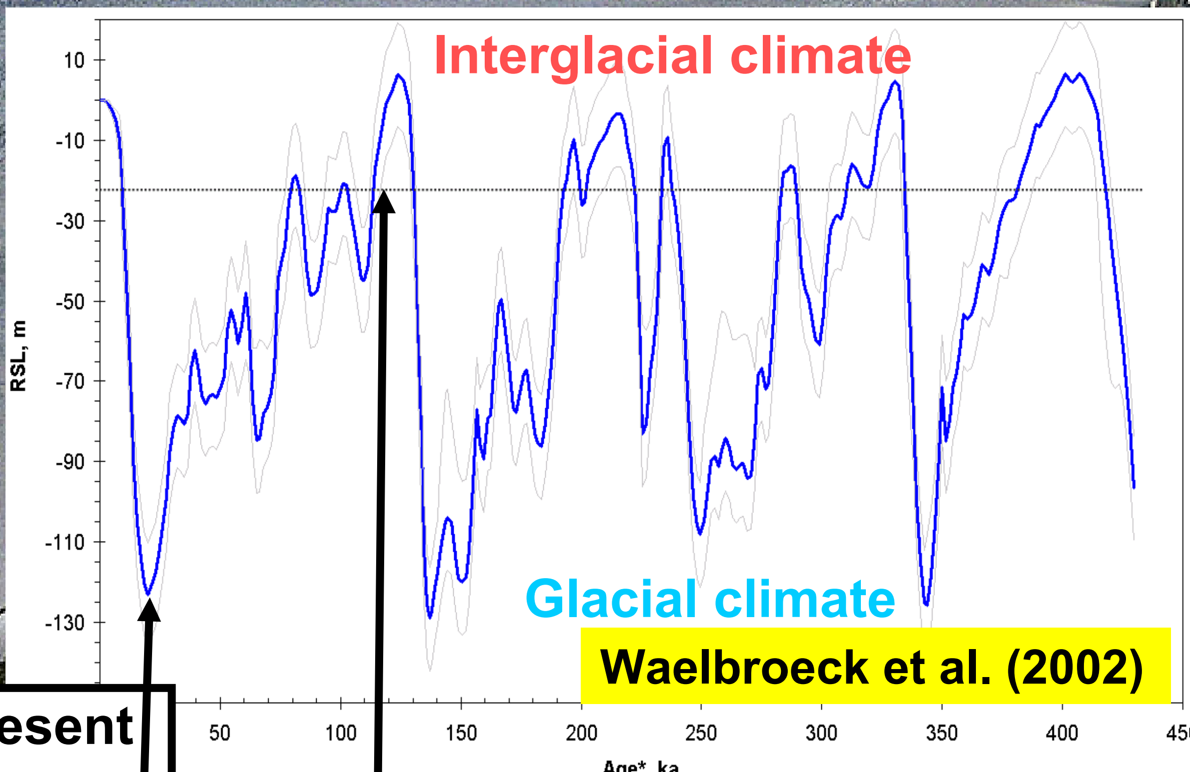
« A feature of recent climate change research is the breadth of observations now available for different components of the climate system, including the atmosphere, oceans, and ***cryosphere****. Additional observations and new analyses have broadened our understanding and enabled many uncertainties to be reduced. New information has also led to some new questions in areas such as unanticipated changes in* ***ice sheets, their potential effect on sea level rise, and the implications of complex interactions between climate change*** *and biogeochemistry. »*

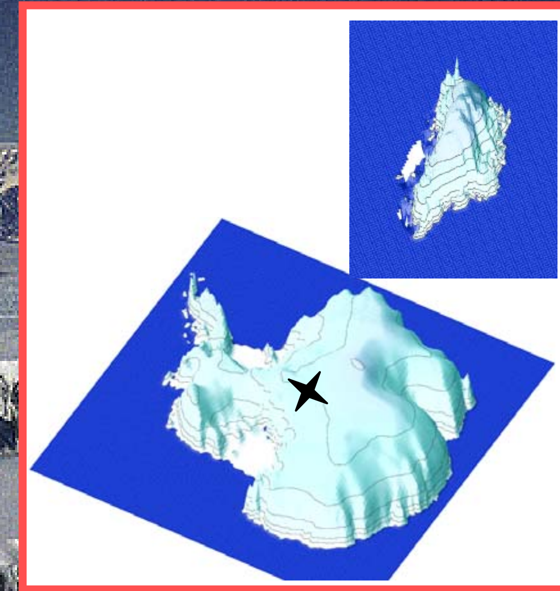
Present-day ice sheets : Greenland and Antarctica

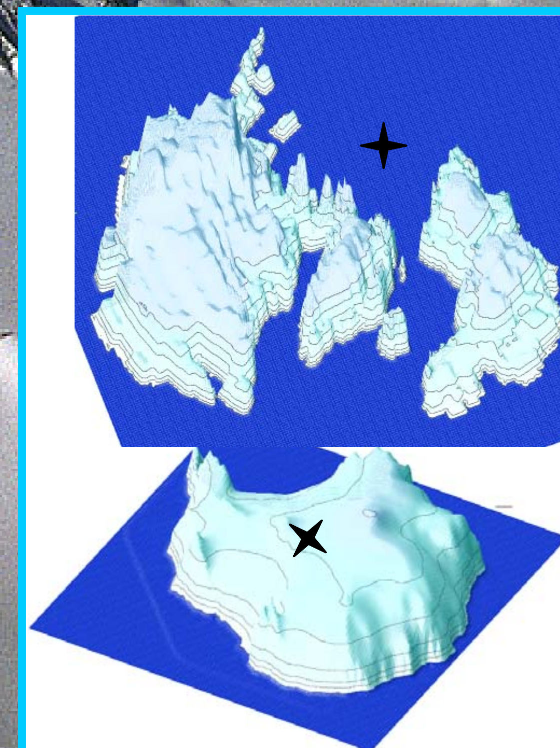


Background (1/2)

- **The last glacial-interglacial cycles**

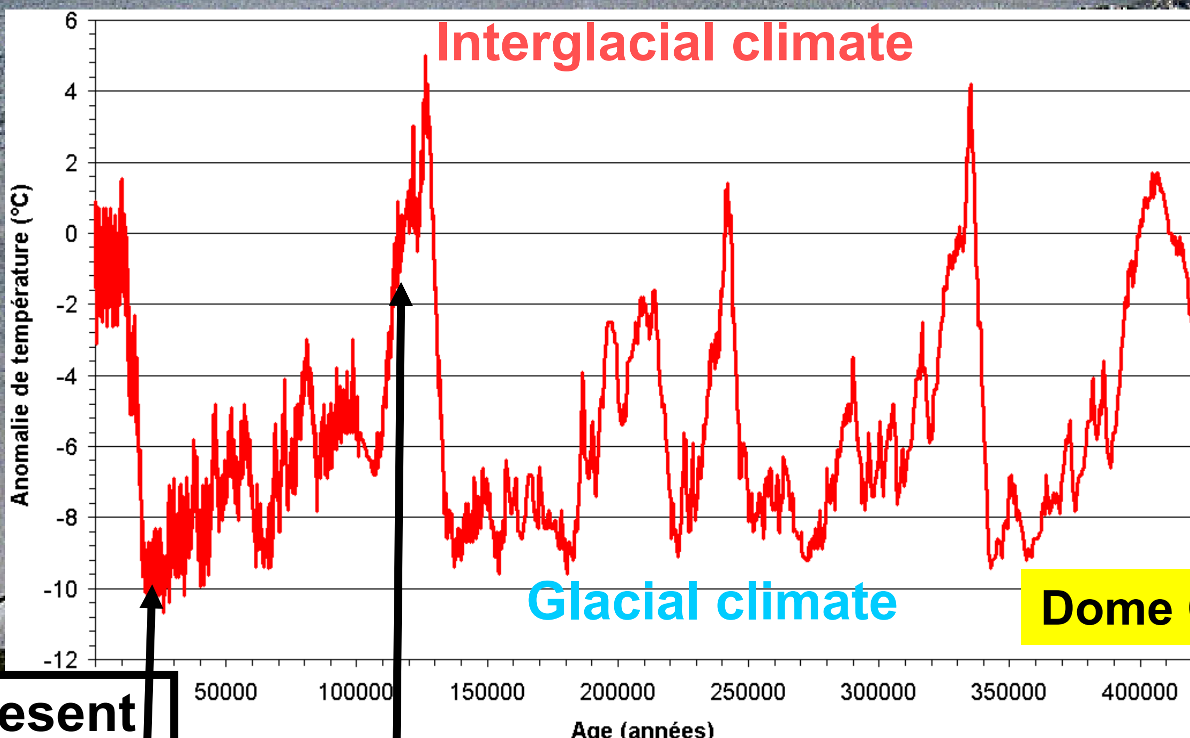


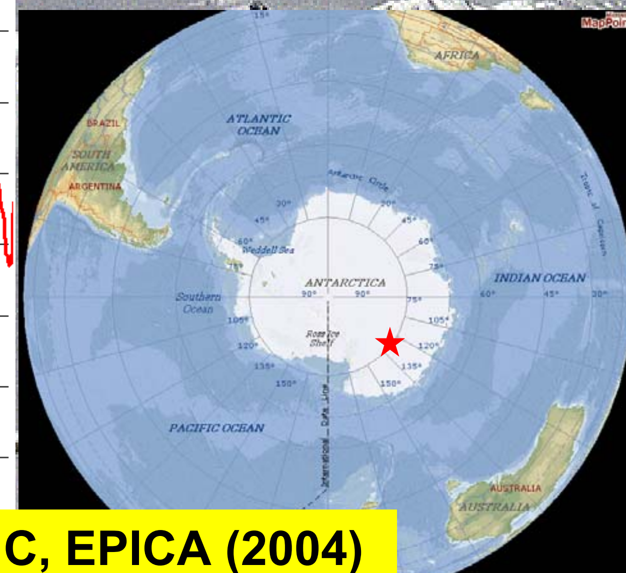




Background (2/2)

- **The last glacial-interglacial cycles**





Dome C, EPICA (2004)

Present Day

LGM

Last Glacial Inception

ΔT➔forced the model

Questions?

1. **Northern hemisphere ice sheets are constraints by data, instead of the Antarctic ice sheet is less documented. During the Last Deglaciation,**

   ➔What is the Antarctic contribution to the sea level rise?

   ➔What are the mechanisms responsible for the Antarctic Deglaciation (last glacial-interglacial transition)?

Conducting experiments to understand the processes

➔ Choice of the models ➔Using a climate and ice sheet models

Integrating long time scales ➔ Choice of the climate model

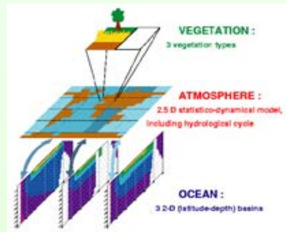
1st time for this new tool

Charbit et al. 2005
Kageyama et al. 2004
Philippon et al. 2006

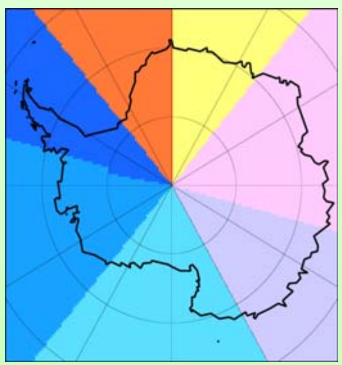
CLIMBER-2: CLIMate-BiosphERe

51° x 10°

2.5° x 20L



Climate model for intermediate complexity for long-term simulations
(Ganopolski et al., 1998 et Petoukhov et al., 2000)



Downscaling: CLIMBER ➔ ISM

ABLATION AND MASS BALANCE:
1/ Annual surface temperature
2/ Summer surface temperature
3/ Annual snow precipitations

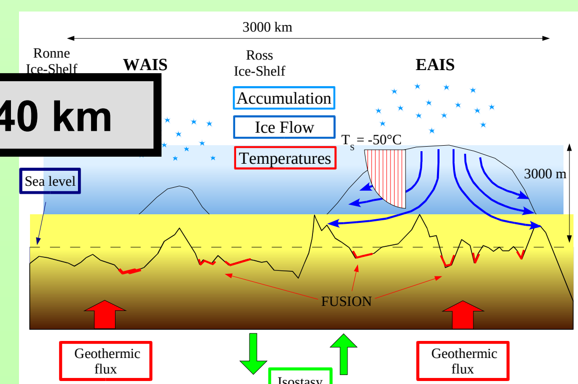
FUSION UNDER ICE SHELVES:
4/ Oceanic temperature

Boundary conditions:
Insolation variation
CO_2 variation
Sea level variation

3-D and thermomecanical ice sheet models (Ritz et al., 2001)

GRenoble model for Ice Shelves and Land Ice
GRISLI:

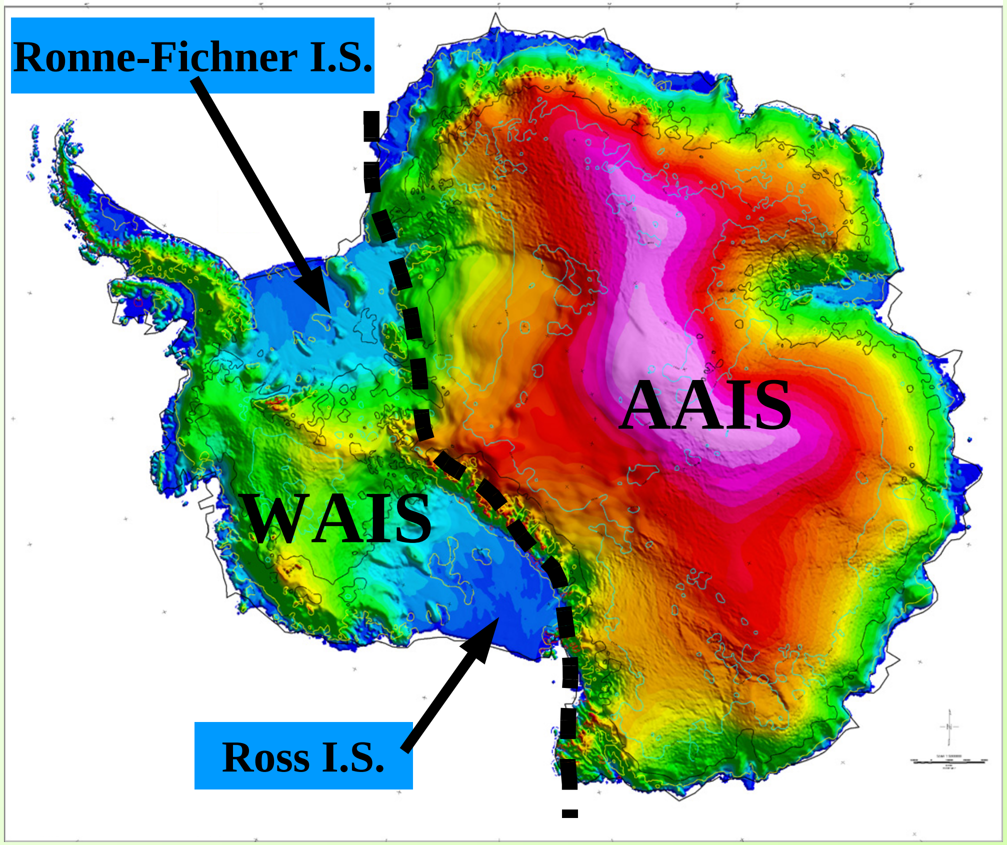
40 km x 40 km



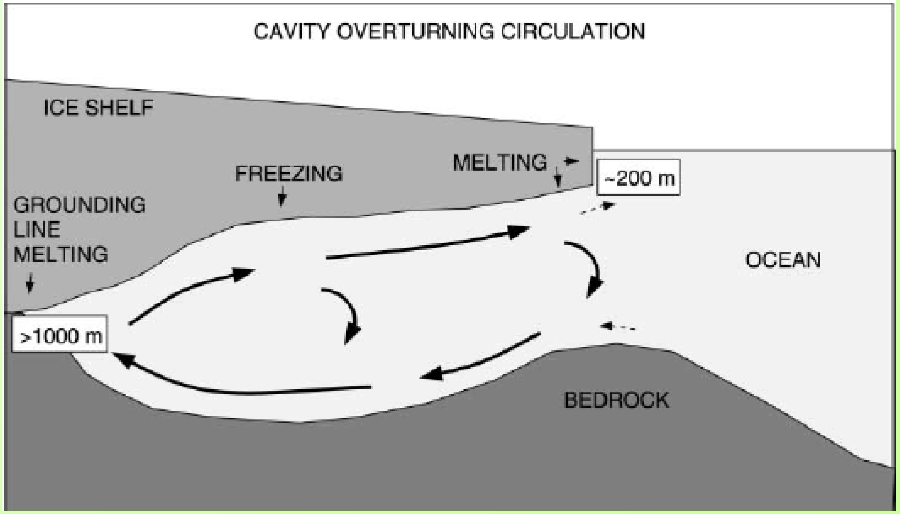
Aggregation: ISM ➔ CLIMBER

1/ Surface types: continental ice, ocean or land ice free
2/ Altitude
3/ Freshwater due to ice sheet melting

The Antarctic ice sheet and its ice shelves



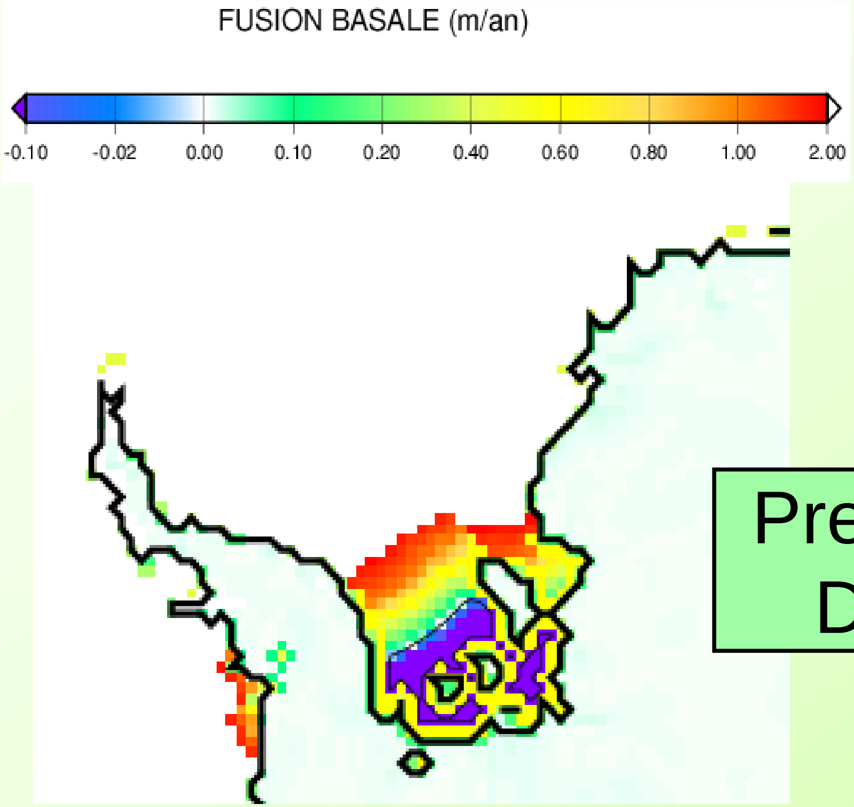
Basal melting under the ice shelves



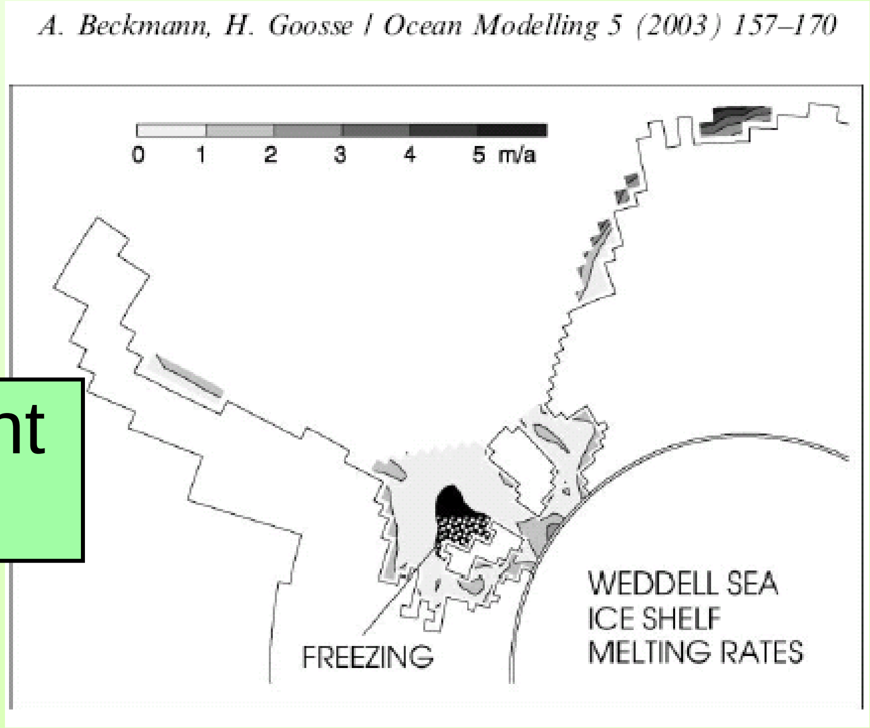
Beckmann and Goosse, 2003

➔Backforce, butressing effect

The Antarctic ice sheet and its ice shelves



Present Day



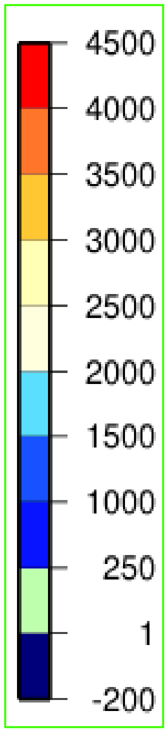
Basal melting equals zero in LGM

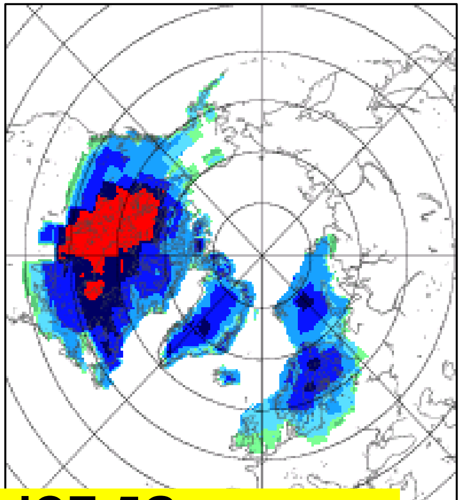
Beckmann and Goosse, 2003

FUSION UNDER ICE SHELVES:
4/ Oceanic temperature

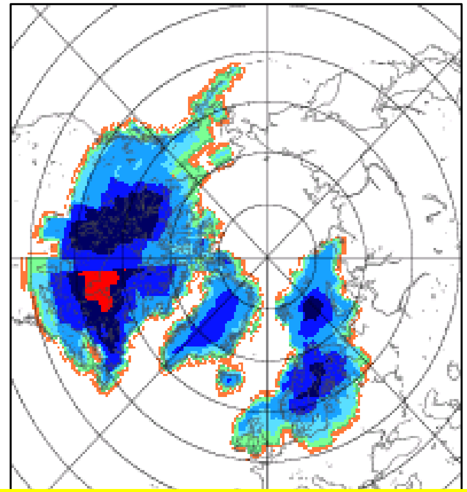
LGM ice sheets reconstructions

(in meters)

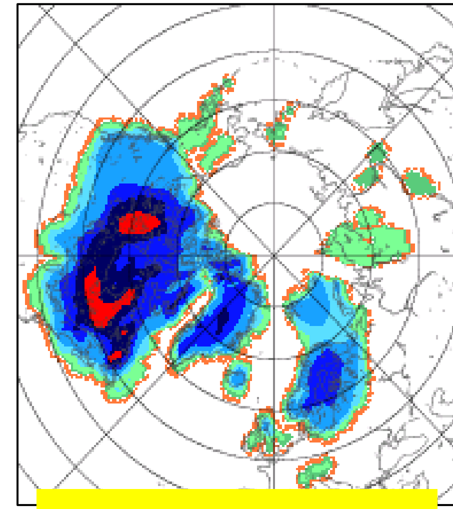




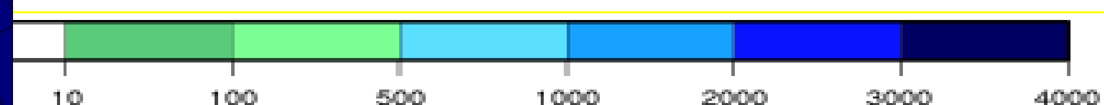
ICE-5G
Peltier (2004)

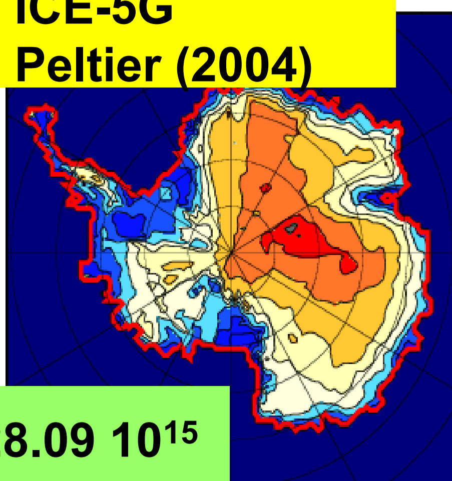


Fleitout and
Cailletaud 2005, 2006



Kurt Lambeck





28.09 10^{15}

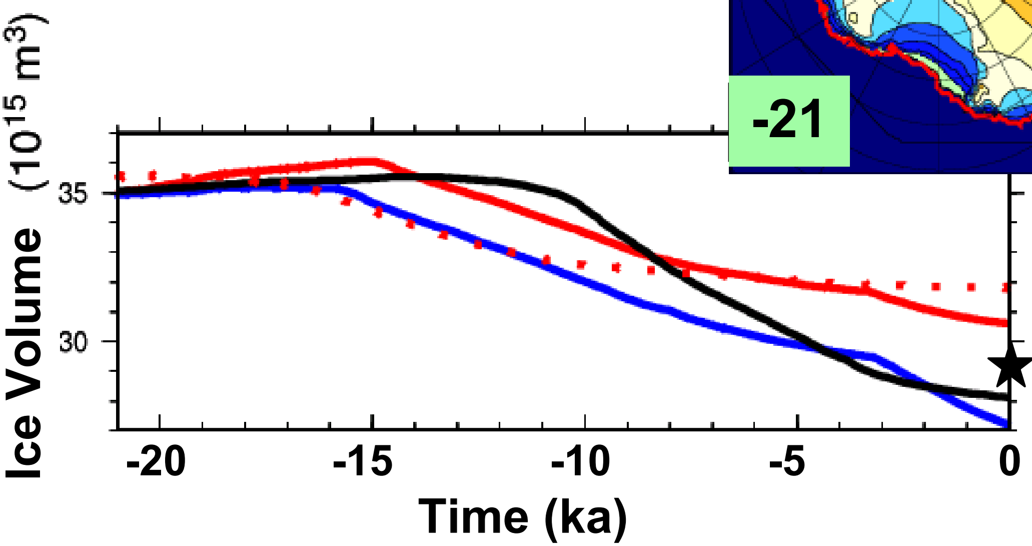
➔2 data constraints!

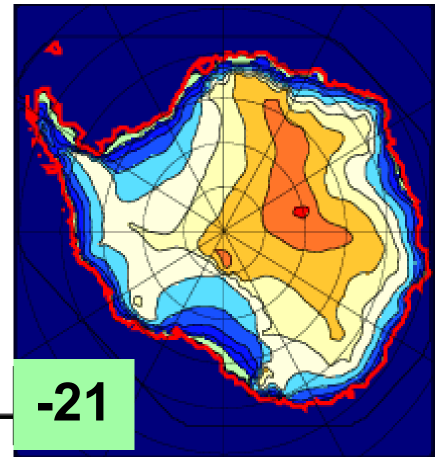
Lambeck and Chappell (2001) ➔ +140 m

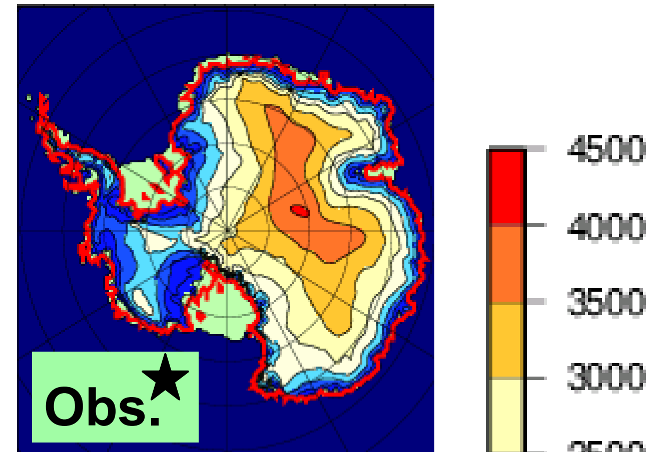
TOTAL HN melting	+127.5 m	+107.5 m	+109.8 m
LAST = ANT.	+12.5 m	+32.5 m	+30.2 m

The Antarctic deglaciation

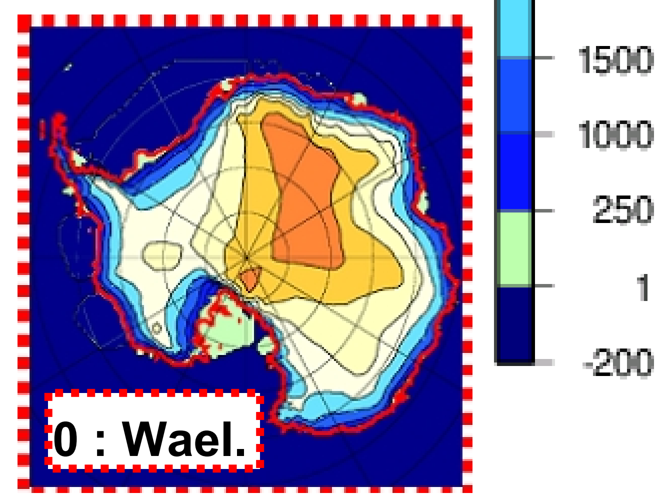
<u>Boundary conditions:</u>
Bassinot et al. 1994
Berger 1978
Petit et al. 1999







Huybrechts et al. (2000)



GRI : GRISLI forced by Vostok climatic fields
STD : CLIMBER coupled with ISM
RONNY = STD -200 m in the Weddell Sea
WAEL = STD but sea level variation from Waelbroeck et al. 2002

➔ Antarctic deglaciation

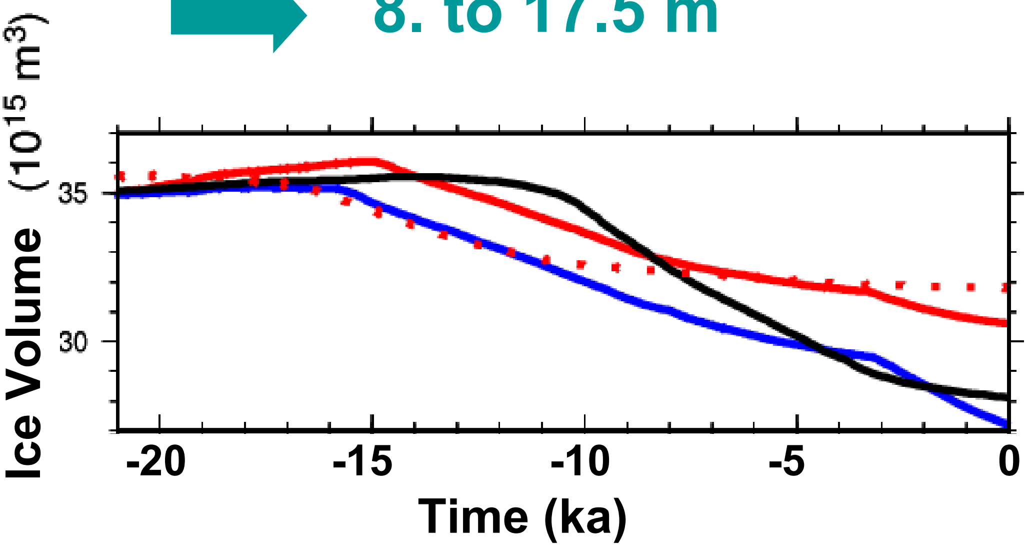
Philippon et al., *EPSL* (2006)
CLIMBER-GREMLINS-GRISLI

The Antarctic deglaciation

Bassinot et al. 1994
Berger 1978
Petit et al. 1999

➔ Sea level rise?

➡ 8. to 17.5 m



Agree with:

7 m, Ritz et al. (2001)
6.1-13.1 m, Bentley (1999)
14 m, Denton and Hughes (2002)
14-18m, Huybrechts et al. (2002)
16.8 m, Peltier (2002)

disagree with:

0.5-2.5 m, Colhoun et al. (1992)
24.7 m, CLIMAP (1976)
27.5 m, Oerlemans (1982)
37 m, Nakada and Lambeck (1988)
38 m, Budd and Smith (1982)

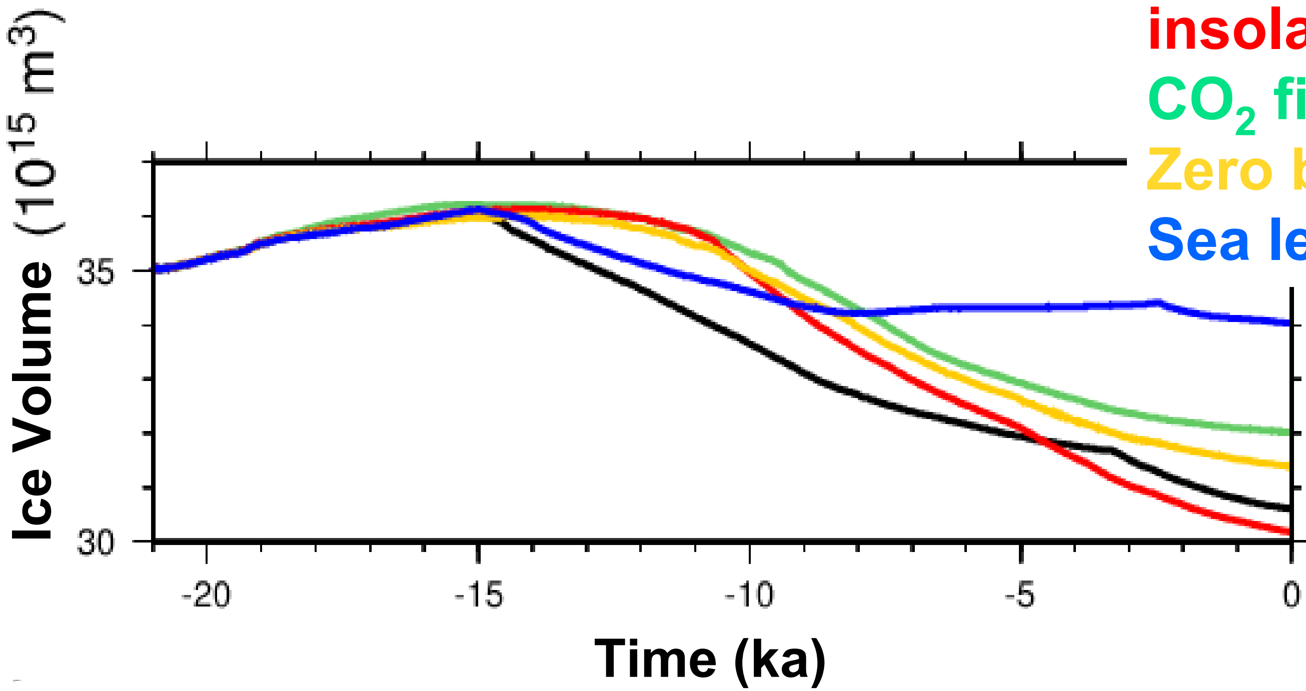
➔ Agreement with a part of the data

➔ Enable to find agreement with some data

Philippon et al., *EPSL* (2006)
CLIMBER-GREMLINS-GRISLI

The mechanisms?

STD Simulation
insolation fixed at LGM
CO_2 fixed at LGM
Zero basal melting
Sea level = -120 m



➔Impact of sea level variation from the Northen hemisphere ice sheet melting

➔Sea level is necessary to destabilize the ice shelves and thus allow the loss of grounded ice

➔Insolation, CO_2 and basal melting parameterization are necessary to trigger the Antarctic ice sheet melting

Philippon et al., *EPSL* (2006)
CLIMBER-GREMLINS-GRISLI

Conclusions about the antarctic ice-sheet interactions during the last Deglaciation

- **A new tool: a climate model coupled with an Antarctic ice sheet model**

  ➔ **tool with a full hydrological cycle (adding Northern and southern hemisphere ice sheets)**

- **1st Antarctic contribution to sea level rise during the last deglaciation with this global tool:**

  ➔ **1st time: Antarctic melting to sea level rise**

  ➔ **Sea level variation ➔ Antarctic melting**

  ➔ **Insolation, CO_2 and basal melting ➔Timing of the Antarctic melting**

Outlooks of this work

- **Account of the CLIMBER bias:**
  - **Implementation of the inversion of temperature above the Antarctic continental plateau**
  - **Better redistribute the precipitations in the CLIMBER grid cell ➔ for example, as a function of the topography**
- **Antarctic initial condition:**

  ➔Using a climate-ice sheet coupled model, coupled with an isostatic model (Luce Fleitout, Kurt Lambeck)

Outlooks

- **Stéfano Bonelli PhD: Evolution of the ice sheets throughout the last climatic cycle**

- **Jorge Alvarez-Solas PhD: the 4xCO_2 scenario could introduce instabilities in the South (T, AABW) and a light answer in the North (T, NADW)**
- **Sylvie Charbit current studies: contribution not zero of the Antarctic and Greenland ice sheets during the actual global warming**

- **NICE project (***Network for Ice sheet and Climate Evolution***):**

  ➔ Pioneering work in the framework of collaborations between European laboratories, feedbacks ice-climate.

Tools: models

Charbit et al. 2005
Kageyama et al. 2004

CLIM*BER*-2: CLIMate-BiosphERe

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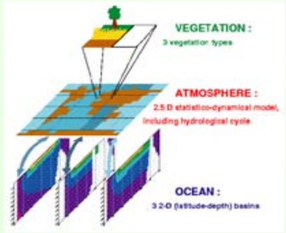

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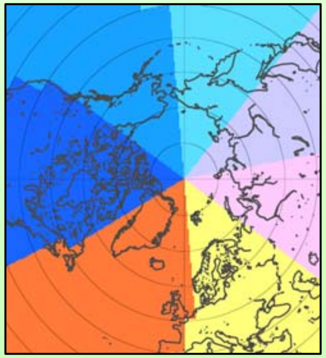

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Boundary conditions:
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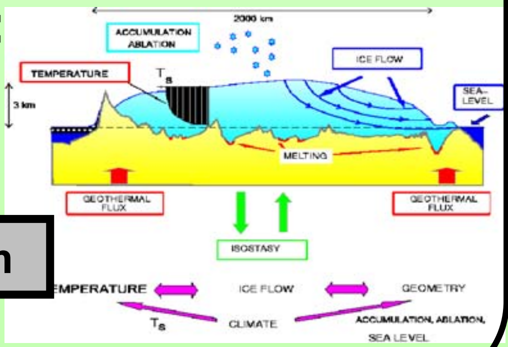
CO_2 variation

Sea level variation

3-D and thermomecanical ice sheet models (Ritz et al., 1997)

GREnoble Model for Land Ice of Northern hemiSphere

GREMLINS:



45 km x 45 km

Aggregation : ISM ➔ CLIMBER

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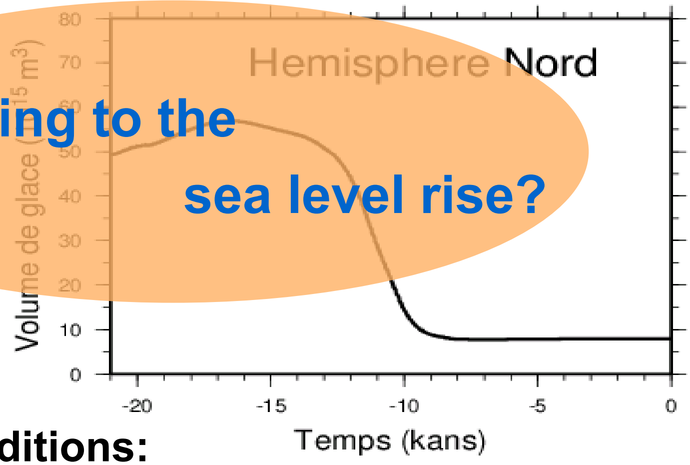
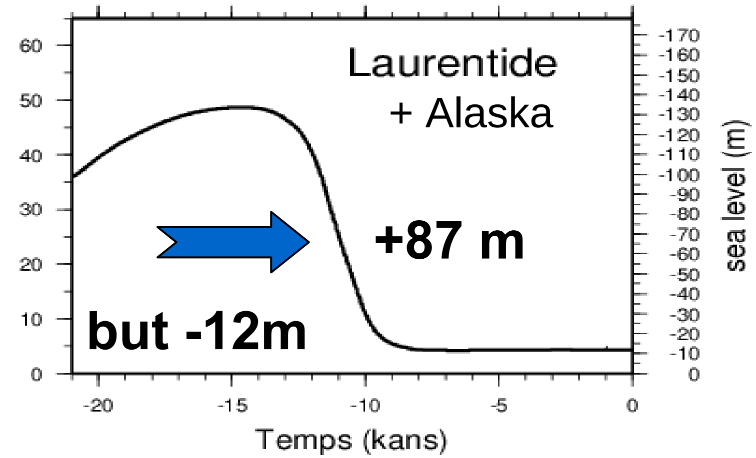
3/ Freshwater due to ice sheet melting

Northern hemisphere deglaciation

Ice melting to the sea level rise?





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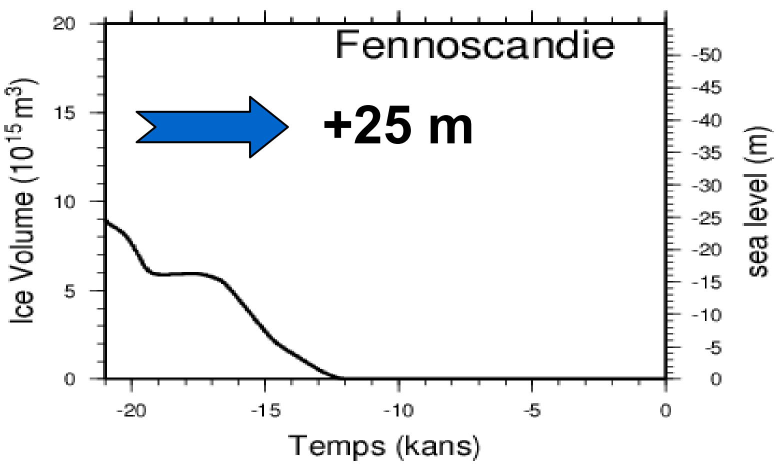
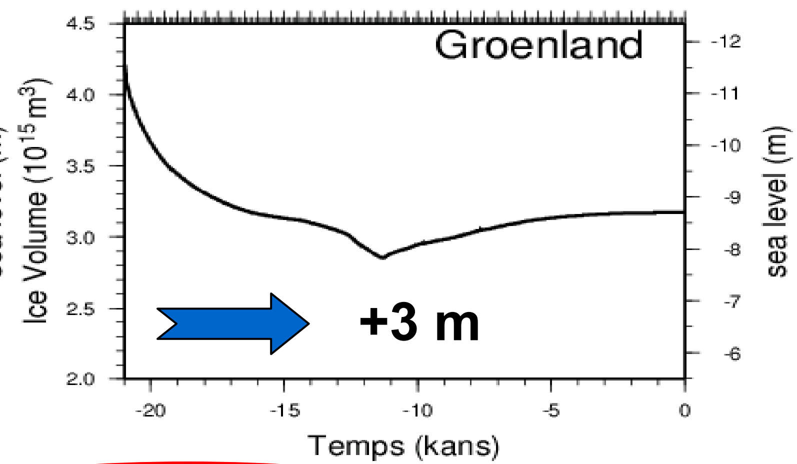
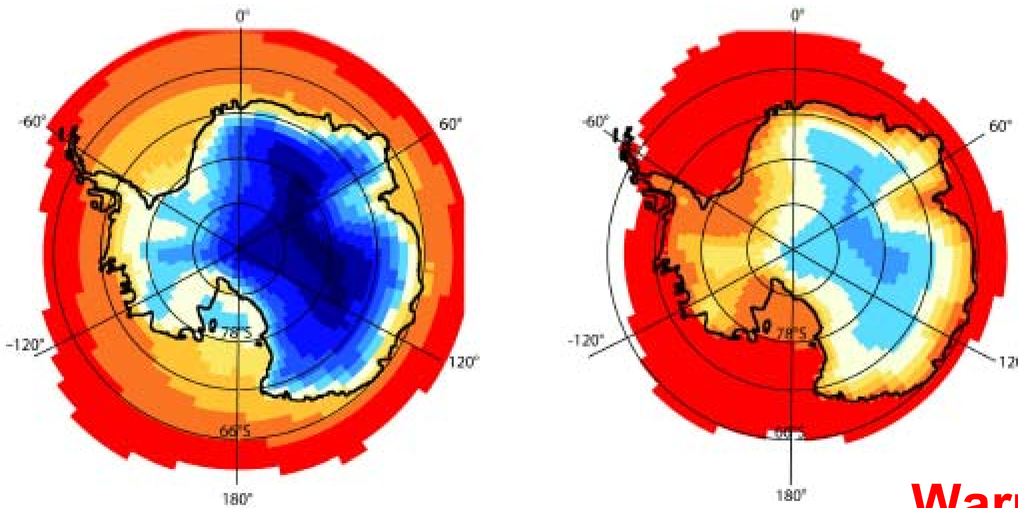


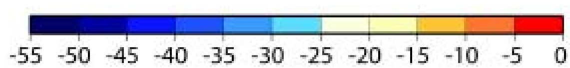


MELTING TOTAL= +115 m but residual ice: -19 m

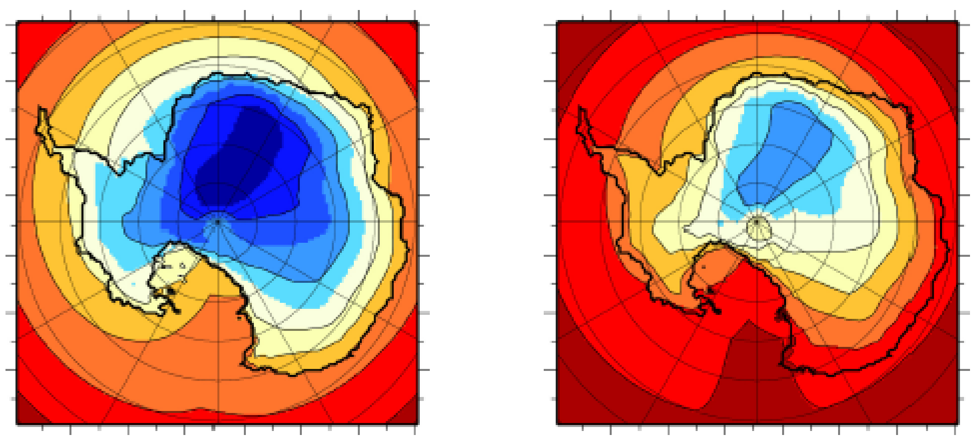
Modern/ERA 40 temperature



ERA 40



Warm bias in the Ross area
Cold bias in the Weddell Sea area

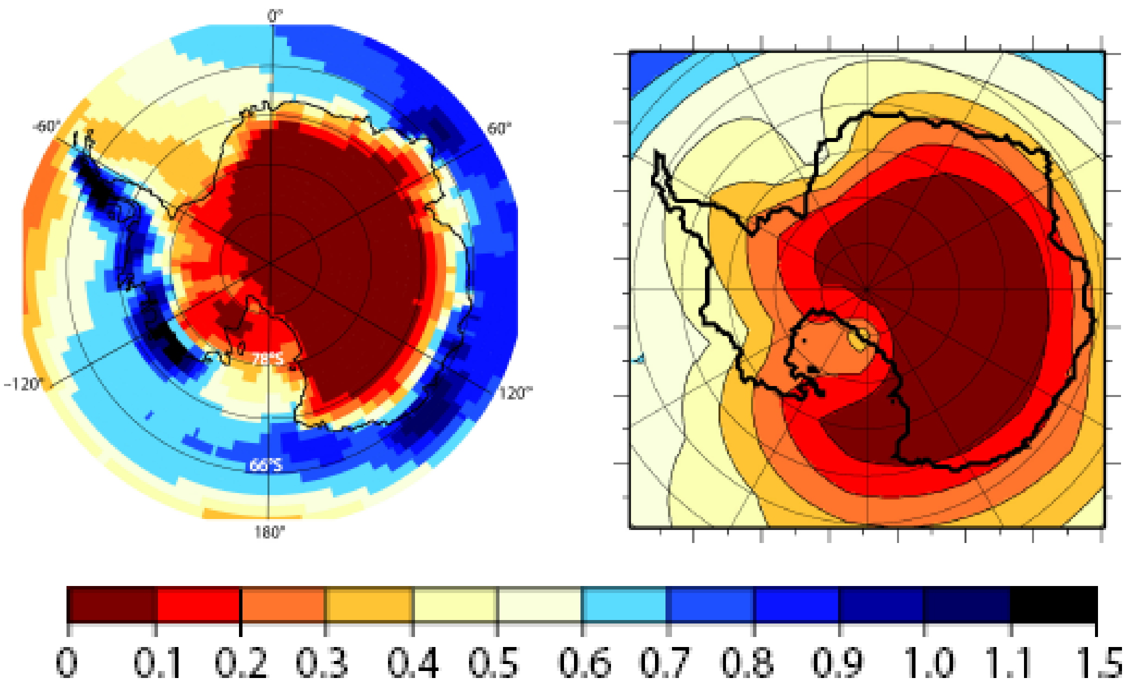


Modern simulation

Annual and summer surface temperature (°C)

Modern/ERA 40 annual snow precipitation

ERA 40



Modern simulation

m/yr

Less accumulation in the Antarctic Peninsula and WAIS
Relative good simulated accumulation in EAIS

The Siberia bias

Present Day residual ice: -19 m