A background image of a vast, flat, white ice sheet under a clear blue sky, with a dark blue ocean in the foreground. The text is overlaid on this image.

Antarctic ice-sheet melting provides negative feedbacks on future global warming

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Major ice sheets on the Earth

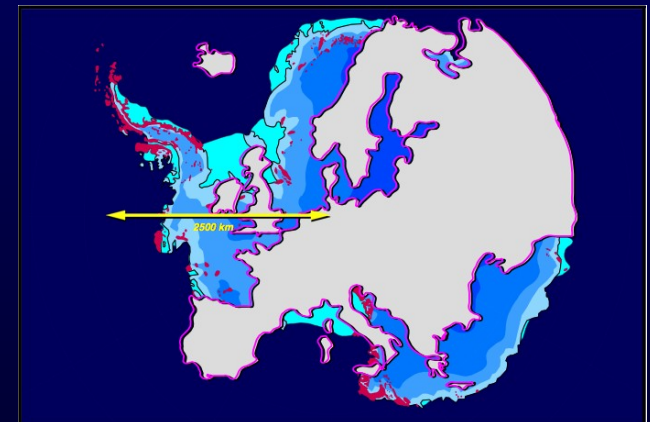
➤ Greenland

- ❖ Grounded ice is equivalent to 7 m of sea-level rise
- ❖ Area of 2 millions km² (81% ice covered)



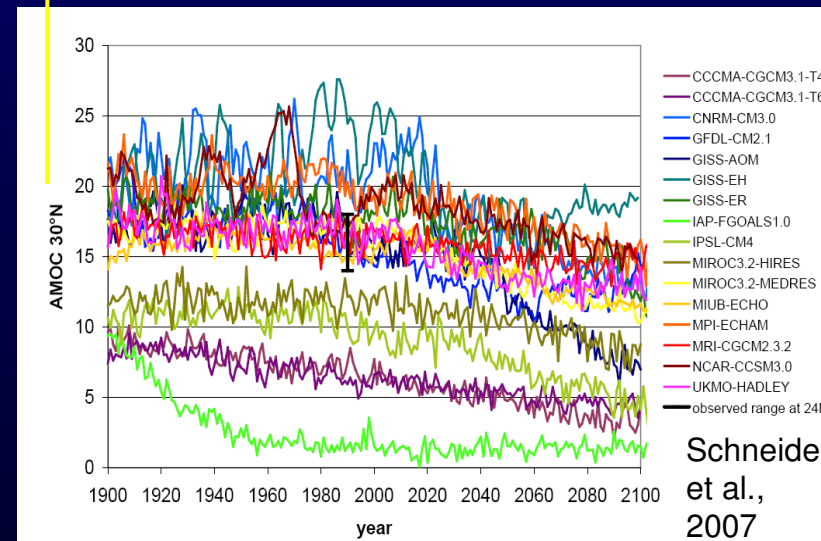
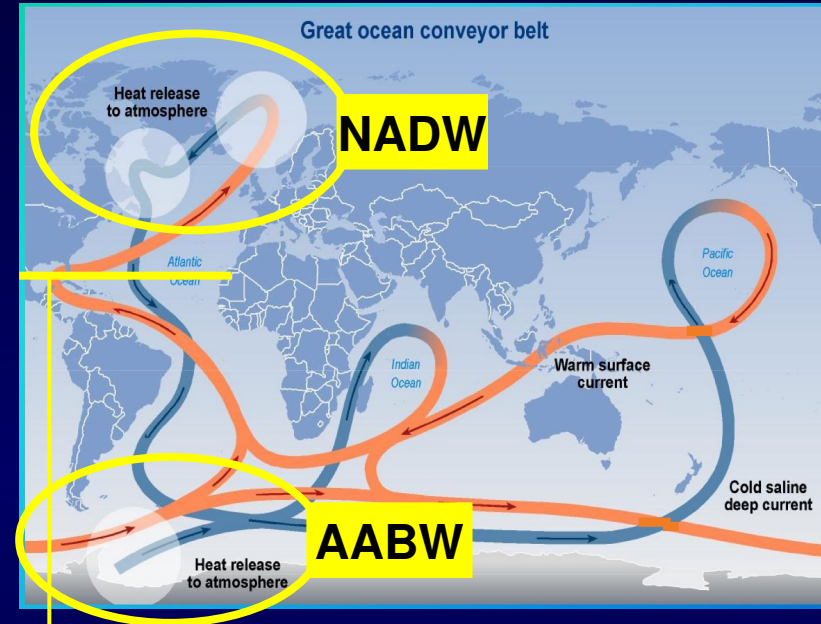
➤ Antarctica

- ❖ Grounded ice is equivalent to 61 m of sea-level rise
- ❖ Area of 14 millions km² (98% ice covered)
- ❖ Huge ice shelves



Thermohaline circulation and climate

- Thermohaline circulation (THC): Oceanic circulation related to temperature and salinity gradient
- Past abrupt climate changes related to changes in the THC (Younger Dryas, McManus et al. 2004) due to massive ice-sheet melting in the North Atlantic
- Southern Ocean have also experienced massive ice-sheet melting (Kanfoush et al. 2000), which could explain some warm periods in the North Atlantic (Bølling-Allerød, Weaver et al. 2003)
- Future of the THC: no Antarctic ice-sheet melting in most models



Outlines

What could be the effect of Antarctic Ice-Sheet (AIS) melting on long term global warming ?

- Can the AIS melt in the future ?
- What will be its effect on surface temperature ?
- What will be its effect on ocean circulation ?
- What are the implications for the projections of sea-level rise ?

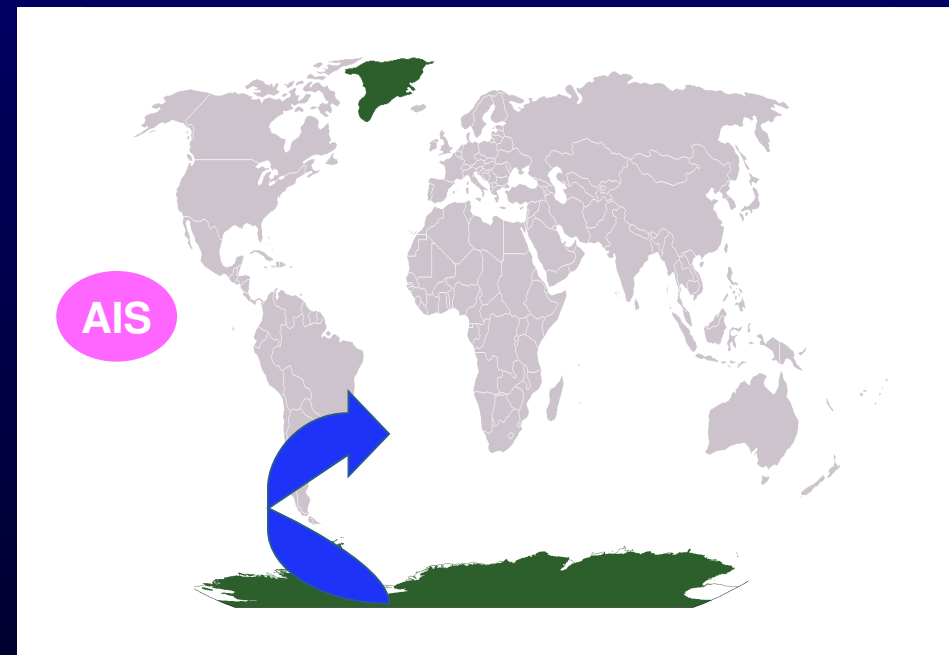
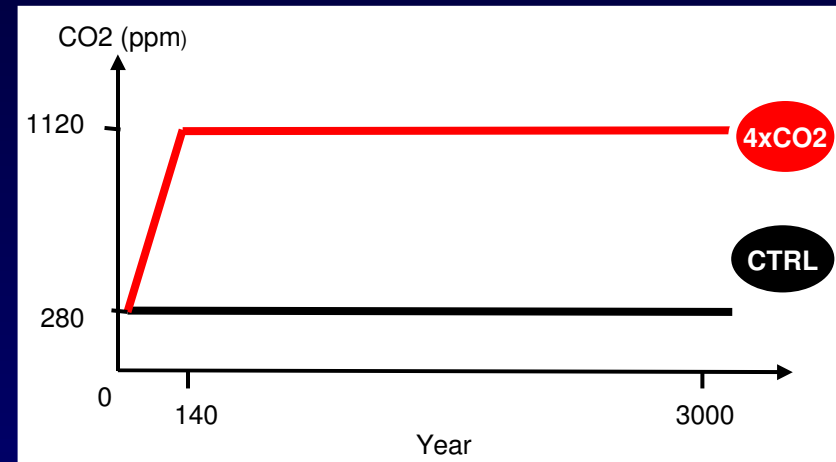
Tools: LOVECLIM earth system model



Experimental design

We analyse several scenario simulations at **4XCO₂**

- **Without** any ice-sheet melting (**fixed**)
- **With** ice-sheet melting from both Greenland and Antarctic ice sheets (**AGIS**)
- **With** melting from Greenland ice sheet only (**GIS**)
- **With** melting from Antarctic ice sheet only (**AIS**)

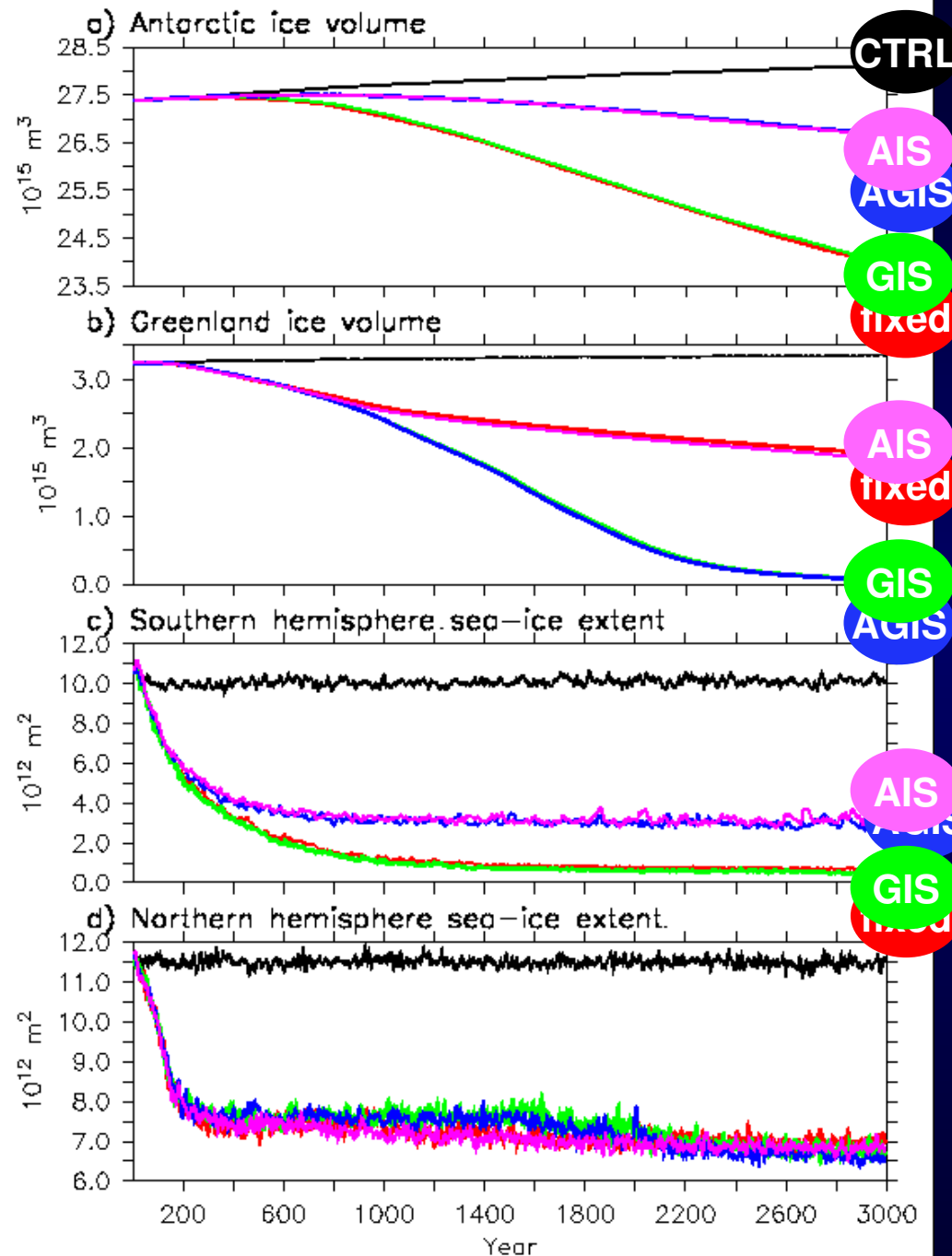


Cryospheric response in scenarios

➤ After 500 years the AIS begins to loose mass in scenarios (**0.14 Sv** into the Southern Ocean in **AIS** after 3000 years)

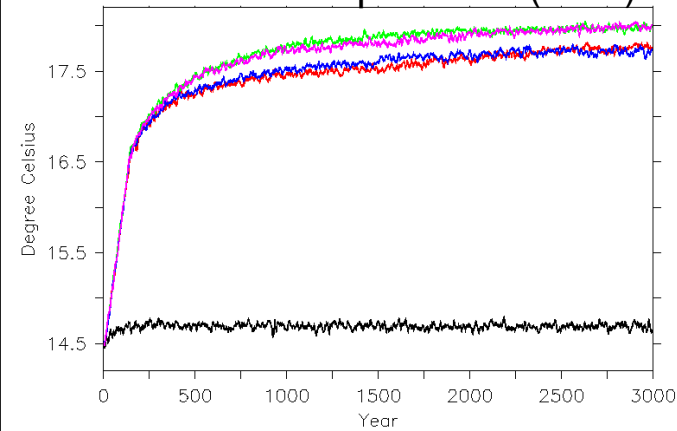
➤ Lag due to the large thermal inertia of the Southern Ocean (same lag for sea-ice cover reduction in the south)

➤ Greenland loses mass after a century and has totally melted in 3000 years in **GIS**



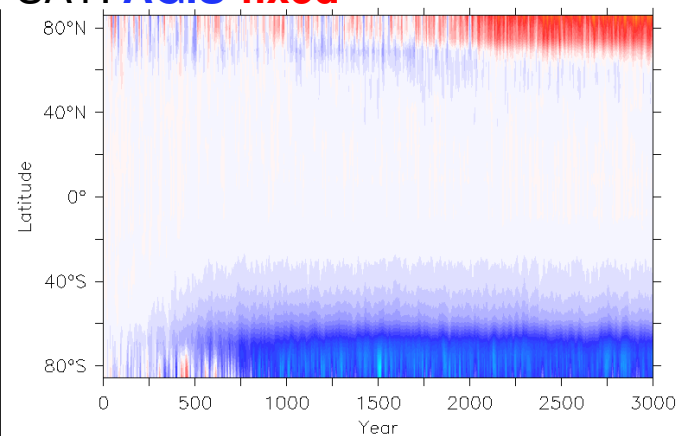
Temperature response in scenarios

Surface Air Temperature (SAT)



AlS melting
reduces the
Climate Sensitivity
by 10%

SAT: **AGIS-fixed**

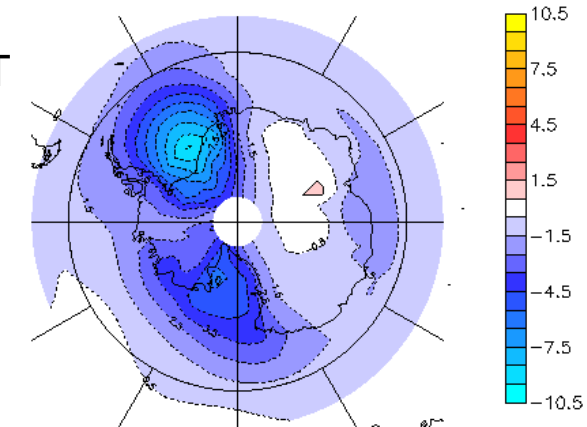


The north is
warming, the
south is cooling

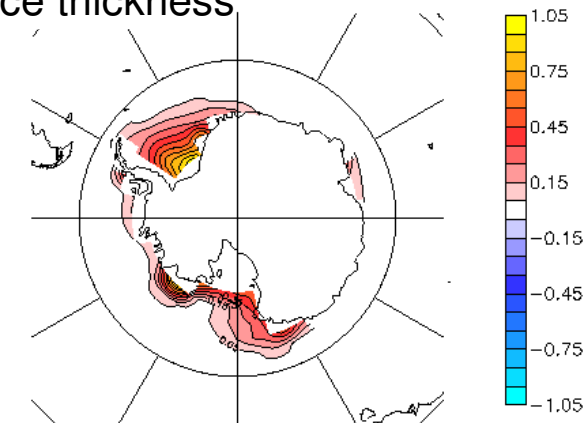
Because of sea-
ice differences

AGIS-fixed: years 2900-3000

a) SAT

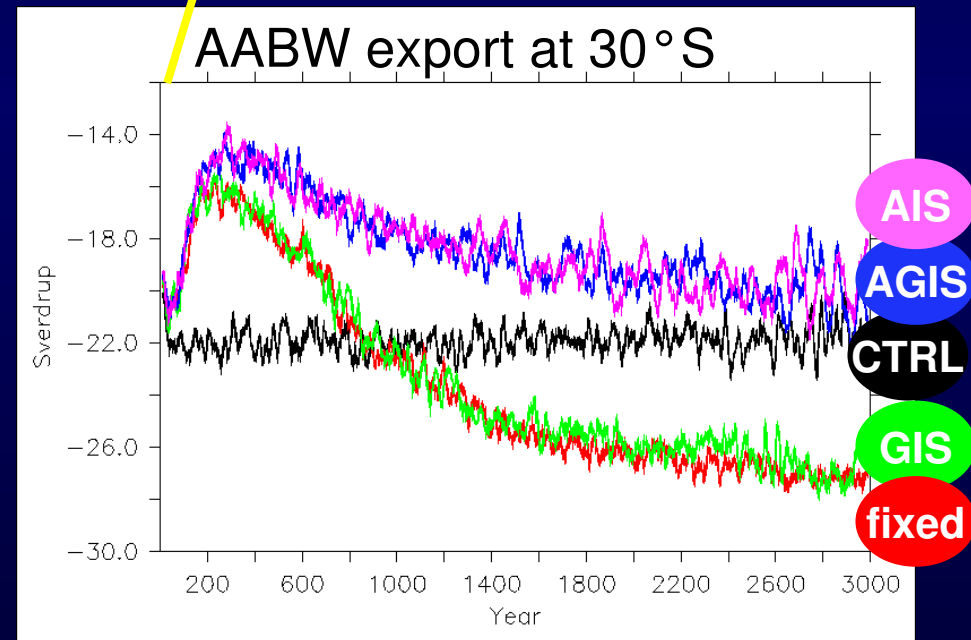
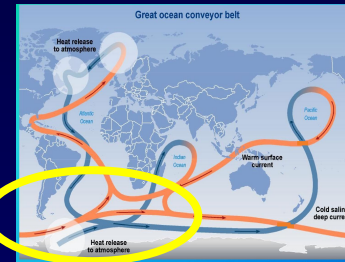


b) Sea-ice thickness



AABW cell response in scenarios

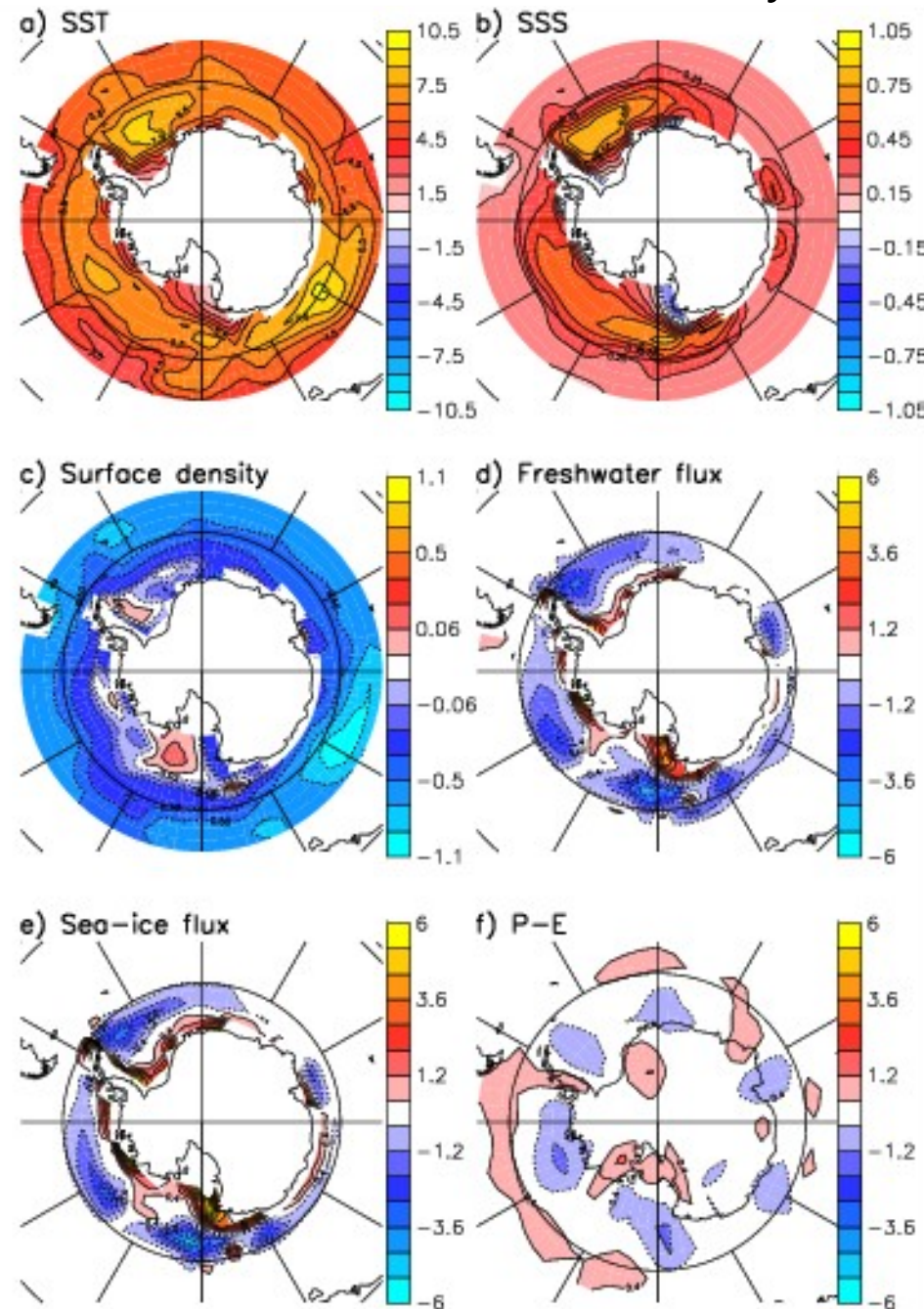
- The AABW cell weakens the first 300 years
- Then it recovers
- It stabilizes around CTRL value with AIS melting
- And 25% over CTRL value without AIS melting
- Why such an increase under global warming in AABW production?



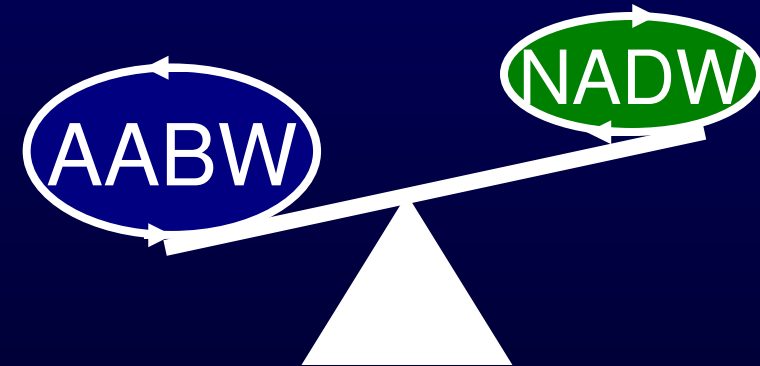
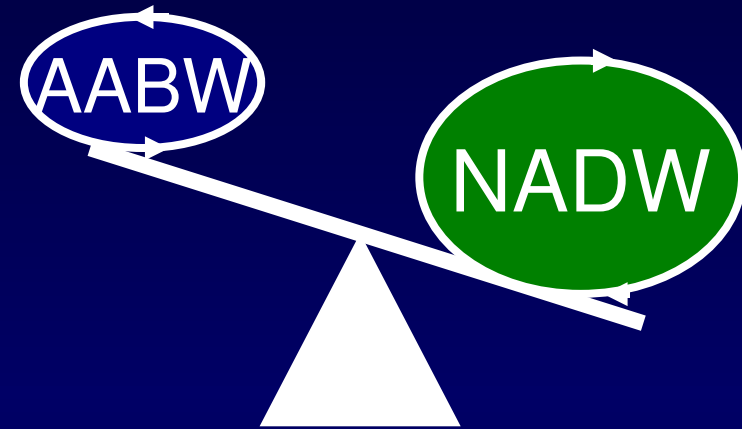
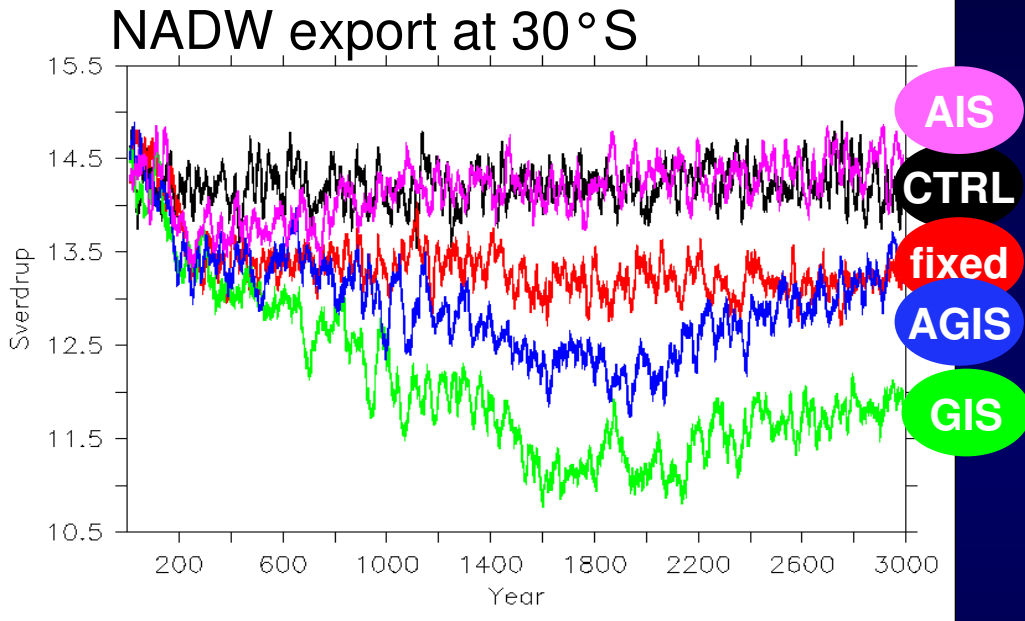
Explanation for the AABW enhancement in scenarios without AIS melting

- SST increases in the Southern Ocean
- As the SSS, which increases surface density at some places, which increases AABW production
- This increase in SSS is mainly due to changes in sea-ice freshwater forcing

4XCO₂ **fixed** - **CTRL** after 3000 years



NADW cell response in scenarios



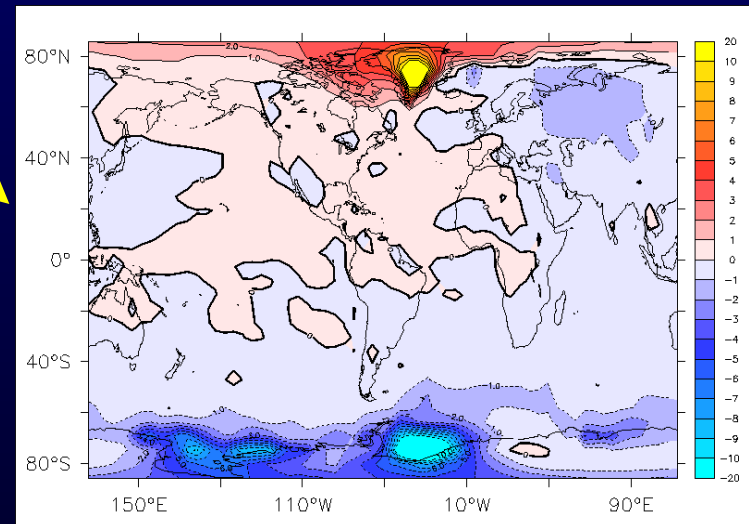
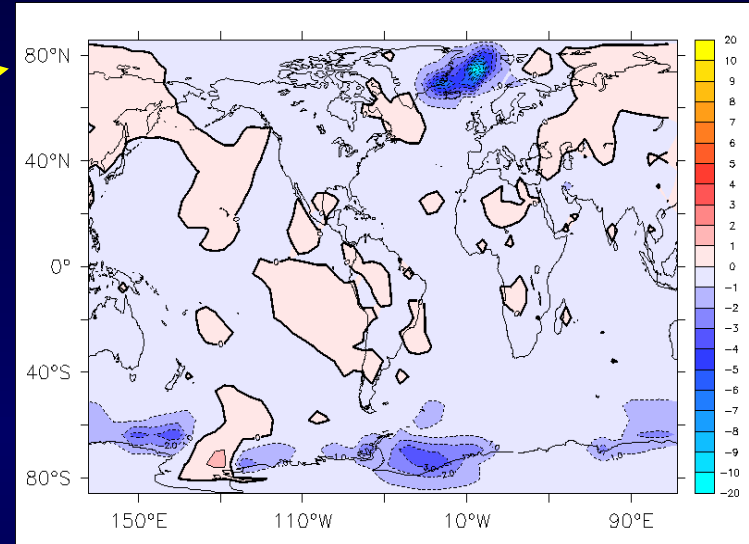
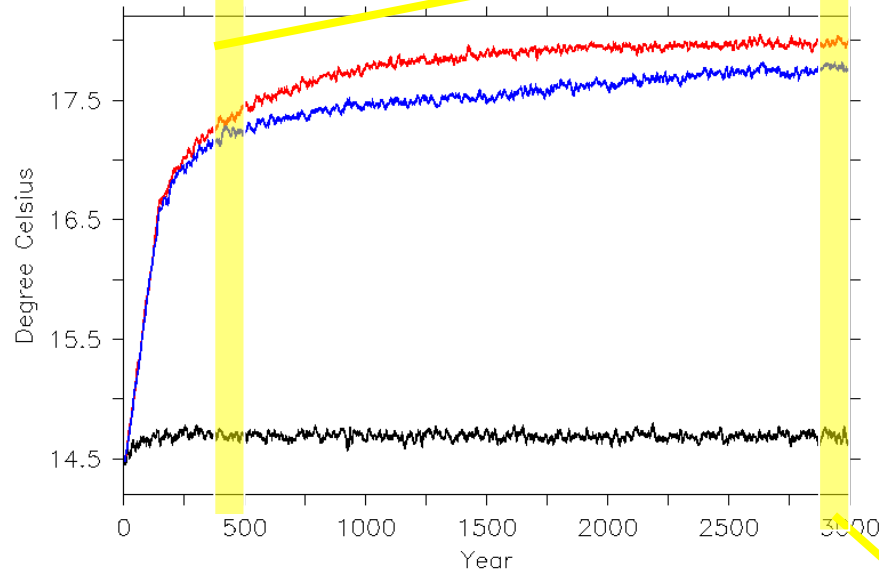
➤ NADW cell weakens more with GIS melting (Driesschaert et al. 2007), while AIS melting reduces this weakening

➤ An illustration of the « bipolar ocean seesaw » process from Stocker et al. (1992)

Climate-ice sheet interactions

CTRL
fixed
AGIS

Mean SAT



Why such different climatic responses?

Climate-ice sheet feedback

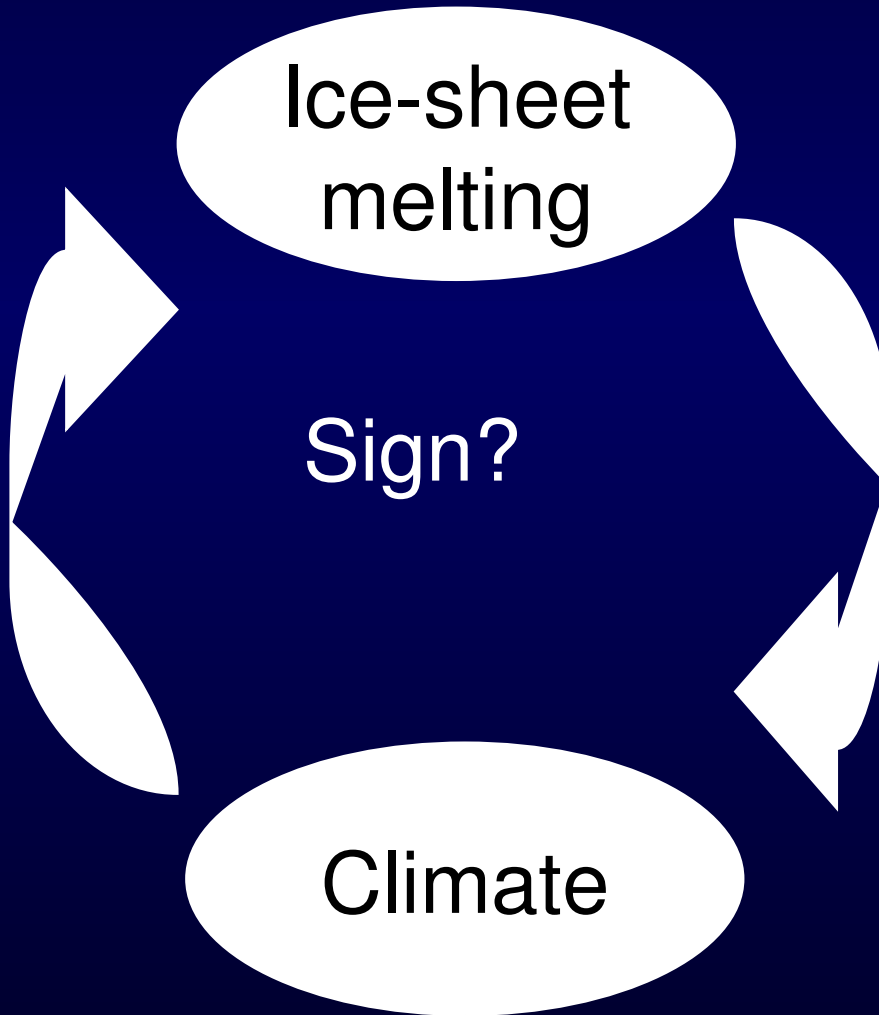
Ice-sheet
melting

Sign?

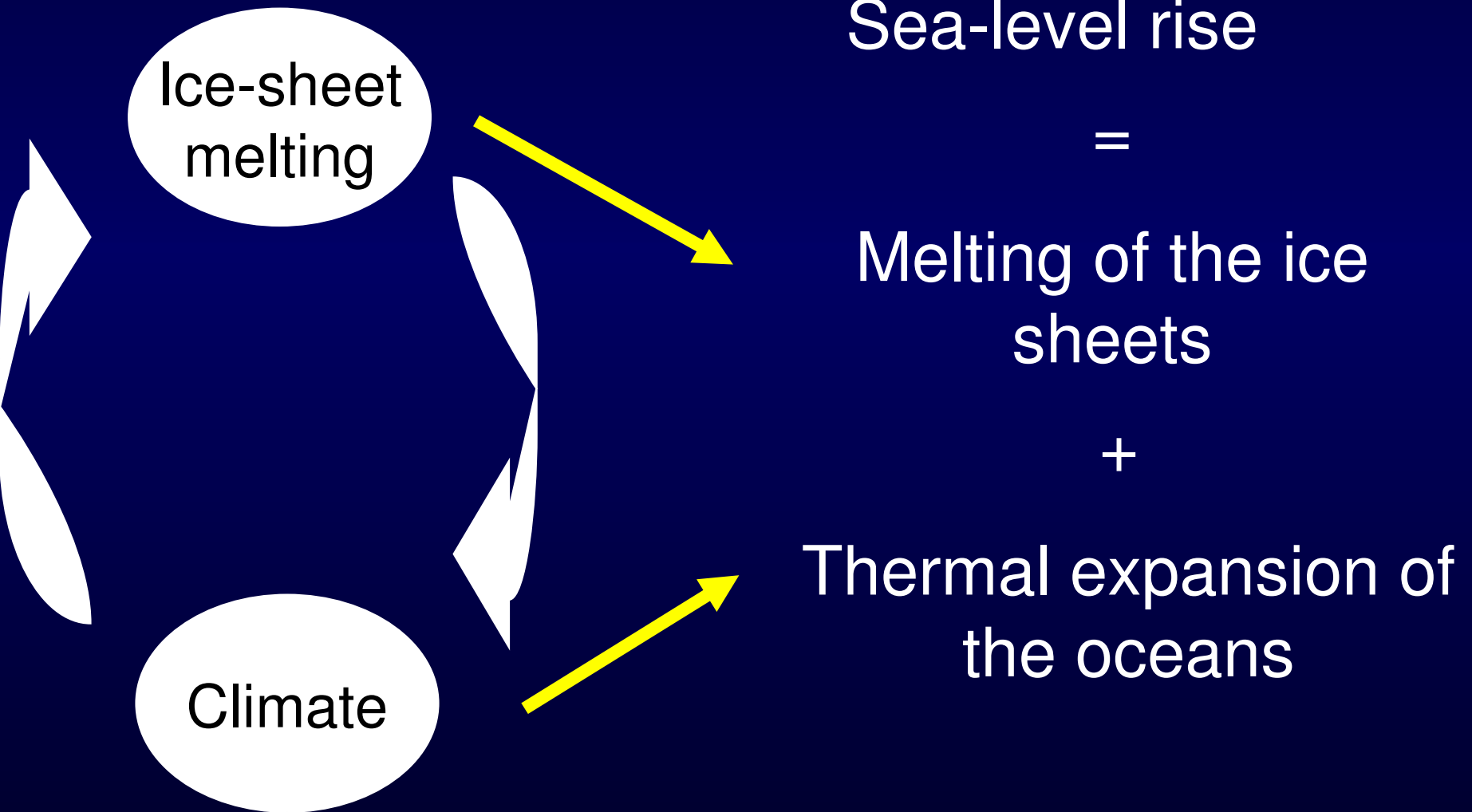
Climate

- Elevation and Albedo (+)
- freshwater input into the oceans (-)
- ...

- Temperature
- Precipitation

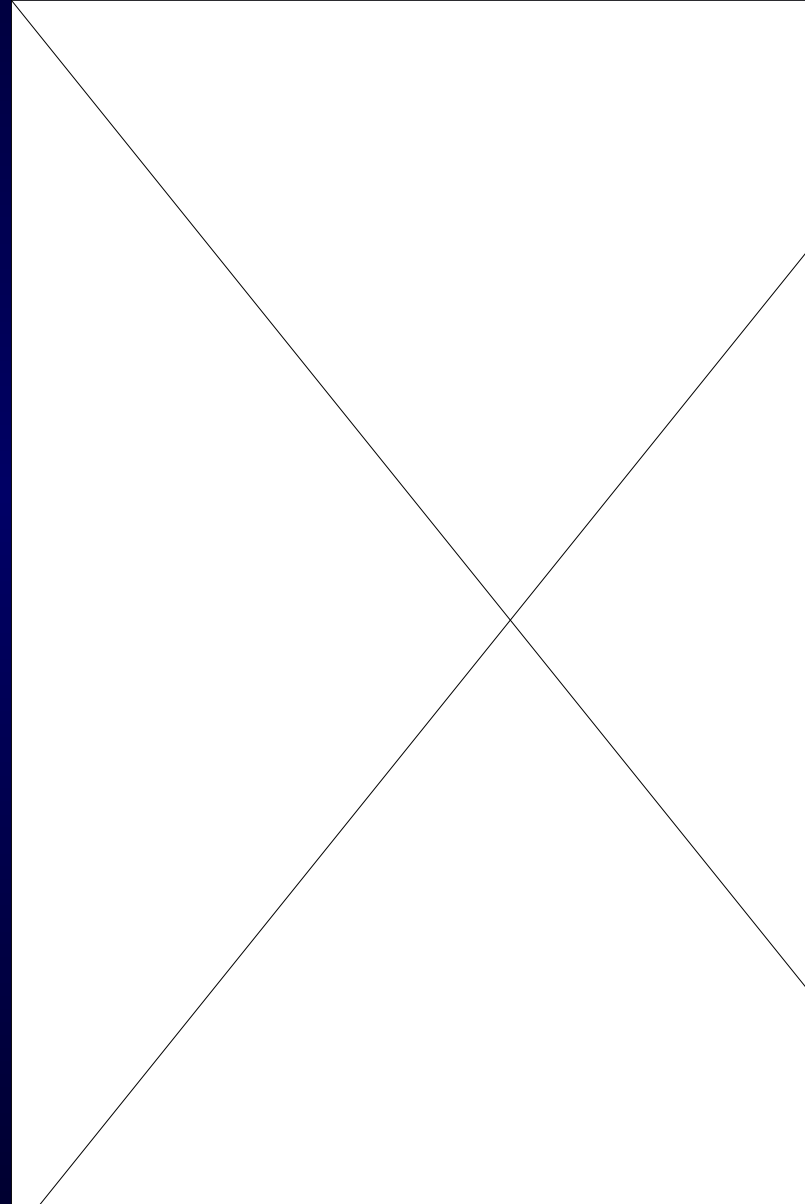


Climate-ice sheet feedback: a sea-level rise viewpoint



Greenland ice sheet

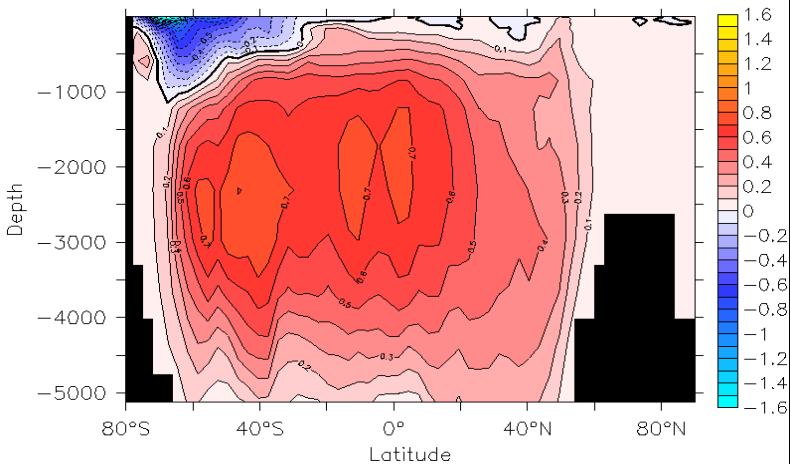
- « on line »: GIS melts as much as **7.9 m** sea-level rise equivalent in **3000 years**
- « off line »: GIS melts as much as **3.4 m** sea-level rise equivalent in **3000 years**
- Strong positive feedback: elevation and albedo feedbacks dominate over negative feedbacks
- Thermal expansion contribution: **1.5 m** «on line», **1.2 m** «off line» = slight negative feedback
- Total positive feedback of **4.6 m** sea-level rise equivalent



Antarctic ice sheet

- « on line »: AIS melts as much as **3.2 m** sea-level rise equivalent
- « off line »: AIS melts as much as **10.0 m** sea-level rise equivalent
- Strong negative feedback: freshwater input feedback dominates over the others

Température de l'océan : on line – off line



- Thermal expansion contribution :
2.3 m « on line »; **1.2 m** « off line »
= important negative feedback

Conclusions

- AIS melting reduces global warming especially in the Southern Hemisphere
- AIS melting reduces the Atlantic THC weakening
- AIS melting is governed by a strong negative feedbacks implying climate interactions
- For all these reasons AIS has to be coupled interactively in coupled models for long-term climate projections

Outlooks

- Test the robustness of the former processes within an ensemble of parameter set in LOVECLIM
- Evaluate the AIS melting effect in other models (by isolating its effect through an experimental design similar to ours)
- Understand the mechanisms for the “bipolar oceanic seesaw” (under debate since a paper from Seidov et al. 2005)



Thank you !

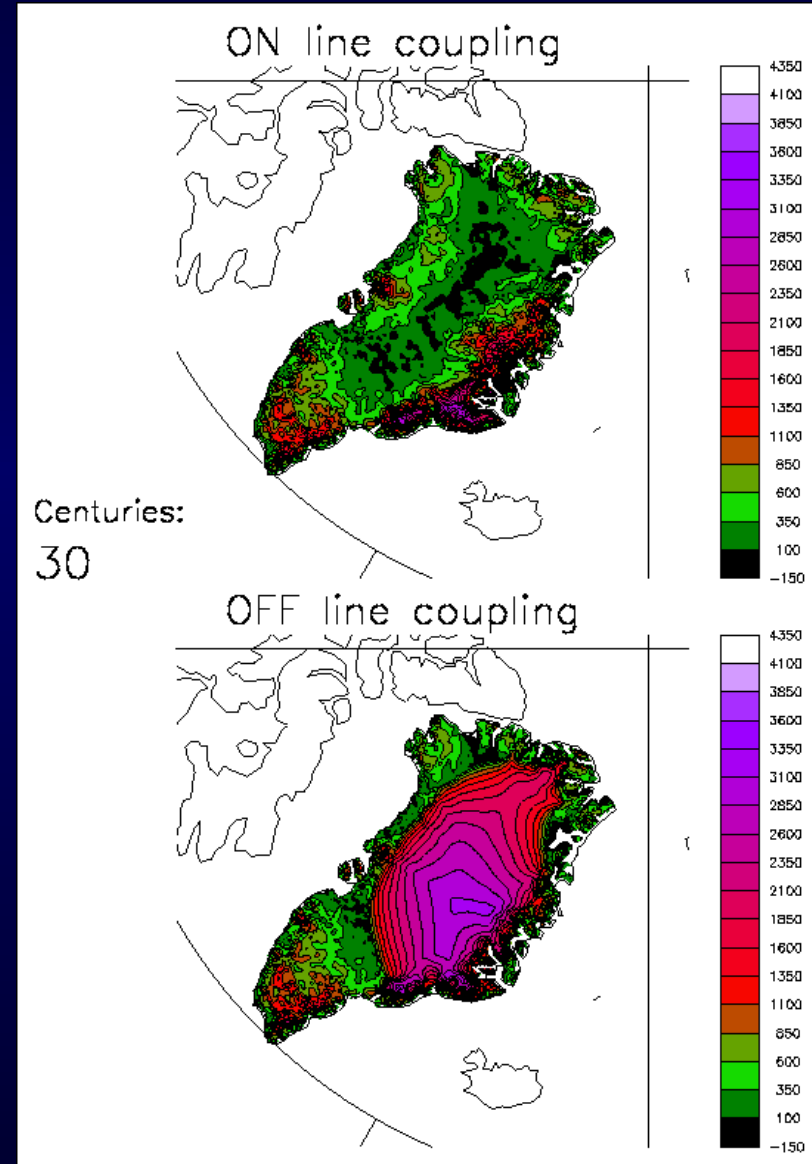
Mailto: swingedouw@astr.ucl.ac.be

Web: http://dods.ipsl.jussieu.fr/dssce/public_html/index.html



Greenland ice sheet

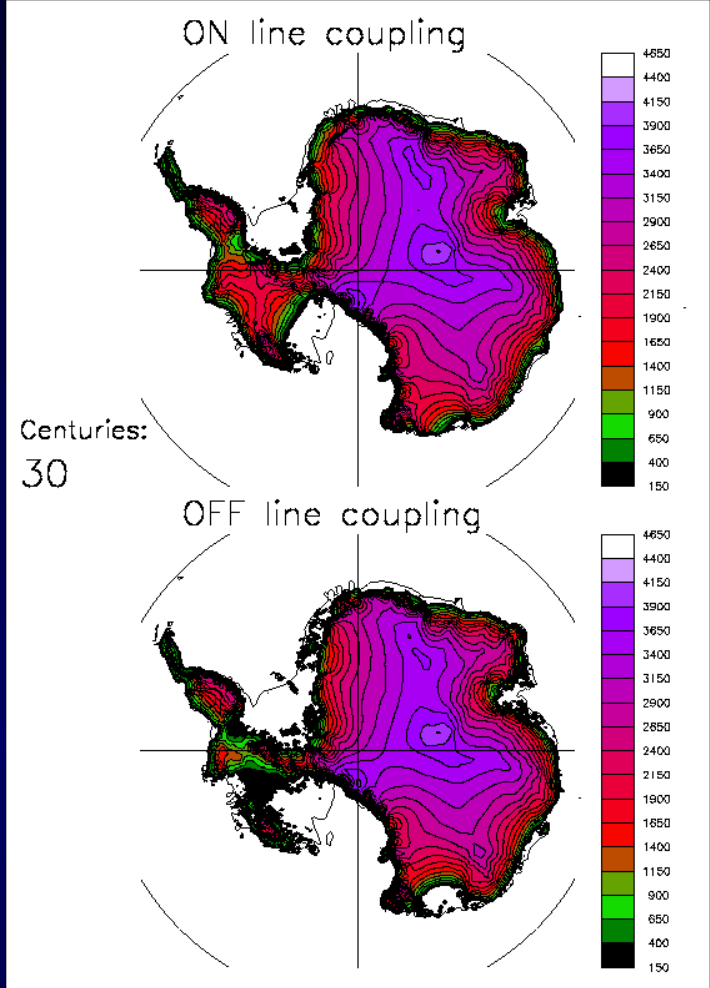
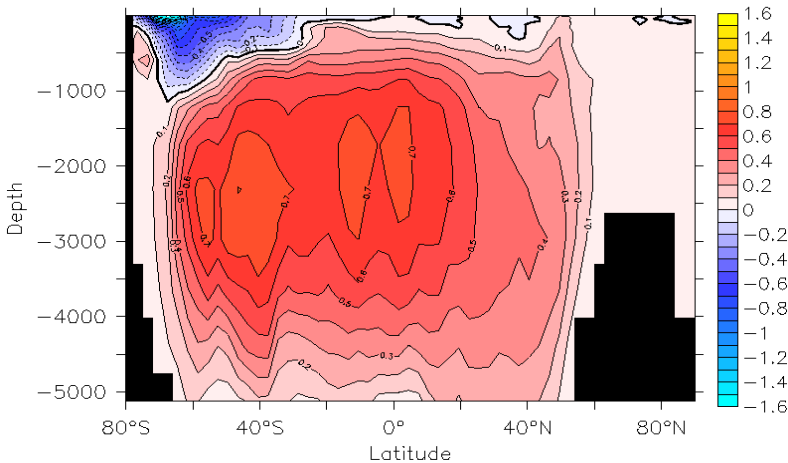
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