Antarctic Ice Sheet simulations using Yelmo ice sheet model and a series of IPSL CM5A2 climate simulations between 17 Ma and 14 Ma

Segalla Diane

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MMCO & MCT

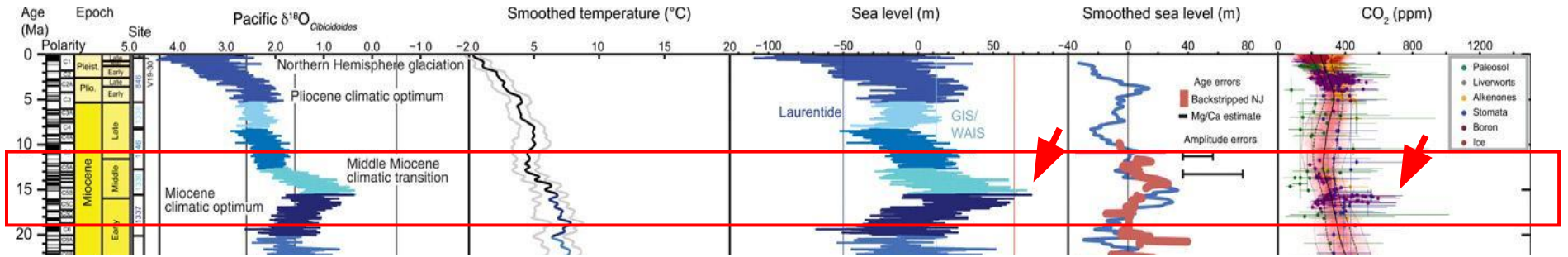
[~17Ma -15 Ma] [~15Ma -13 Ma]

Warm climate

Climate variability due to changes in orbital parameters

One ice sheet : Antarctica → sea level

pCO2 : 400 -600 ppm



Summary of Cenozoic benthic foraminiferal, temperature, sea level and CO2 record, Miller et al. 2020, DOI: 10.1126/sciadv.aaz1346

PROBLEMATIC

How does the AIS

- react **with higher pCO2** than during pre-industrial period ?
- respond to **changes in astronomical forcings** during MMCO & MCT ?

Methodology & BC for AOGCM & ISM simulations

CLIMATE MODEL
IPSL CM5A2

force the ISM with climate outputs

ICE SHEET MODEL
YELMO

Run climate steady state snapshots at Miocene and sensitivity tests with pCO2 & orbital parameters forcings

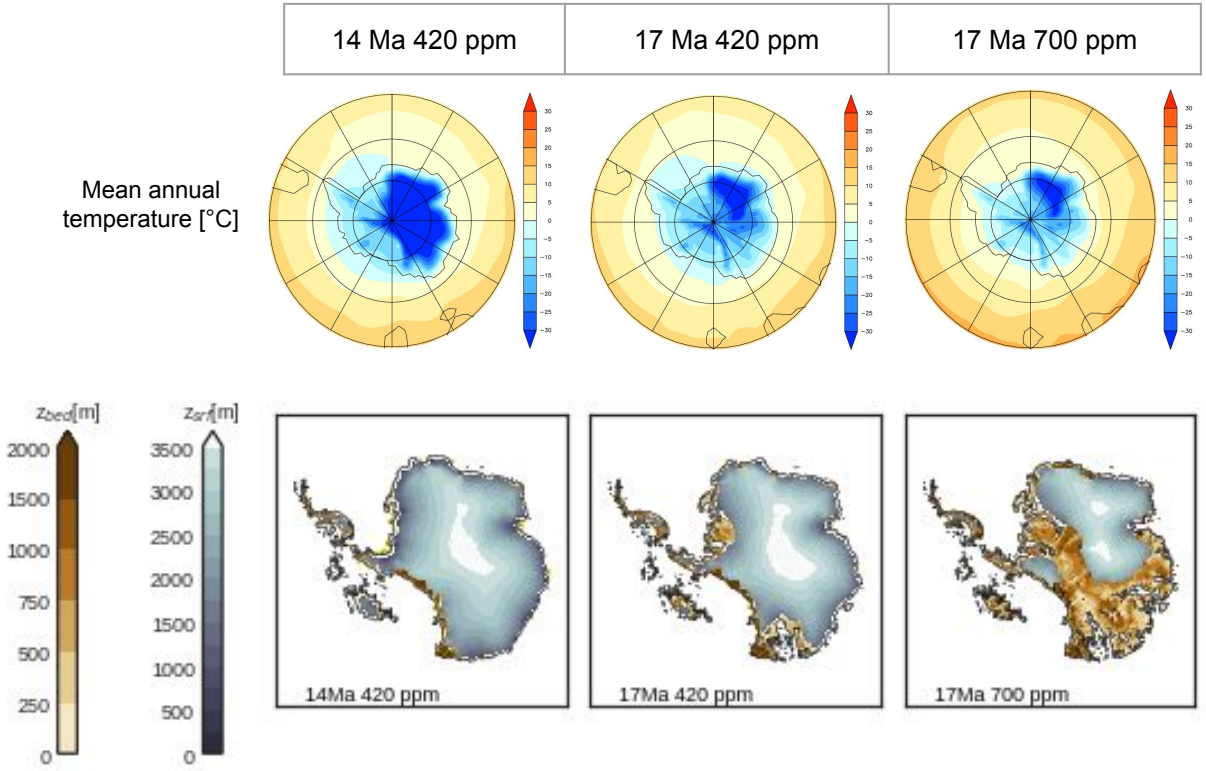
Climate forcings used to perform simulations to study different AIS enveloppes

Boundary Conditions

	14 Ma	**17 Ma**
Paleotopography	Frigola et al. 2018	
pCO2	420 ppm	420 ppm & 700 ppm
Orbit	present day & min + max insolation (75°S)	
Ice Sheet	80 % of PD	50 % of PD

Results IPSLCM5A2 -YELMO outputs

Forcings impact : **pCO2**



the most sensitive

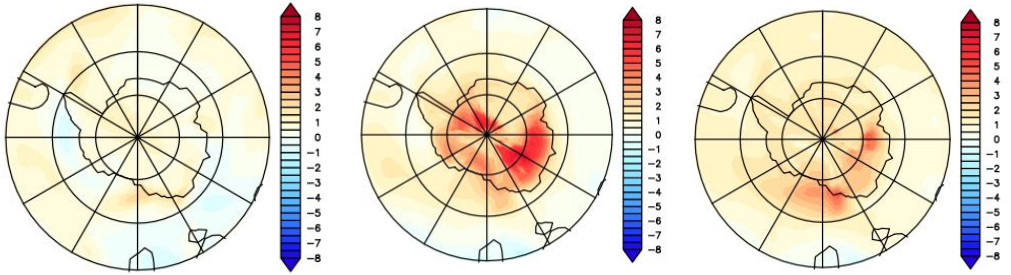
- Warm climate
  - ➢ less AIS
- pCO2 impact stronger at 17 Ma 700 ppm

Results IPSLCM5A2 -YELMO outputs

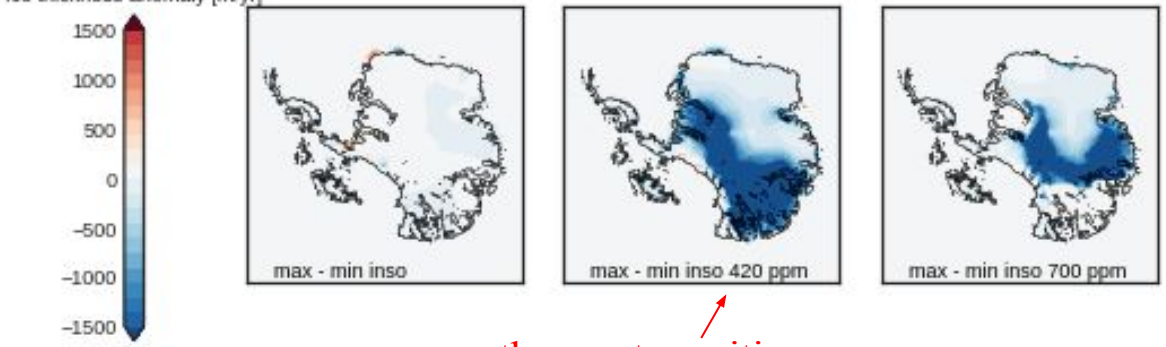
Forcings impact : **insolation**

14 Ma 420 ppm Max - Min insolation	17 Ma 420 ppm Max - Min insolation	17 Ma 700 ppm Max - Min insolation

Mean annual temperature anomalies [°C]



Ice thickness anomaly [m/yr]



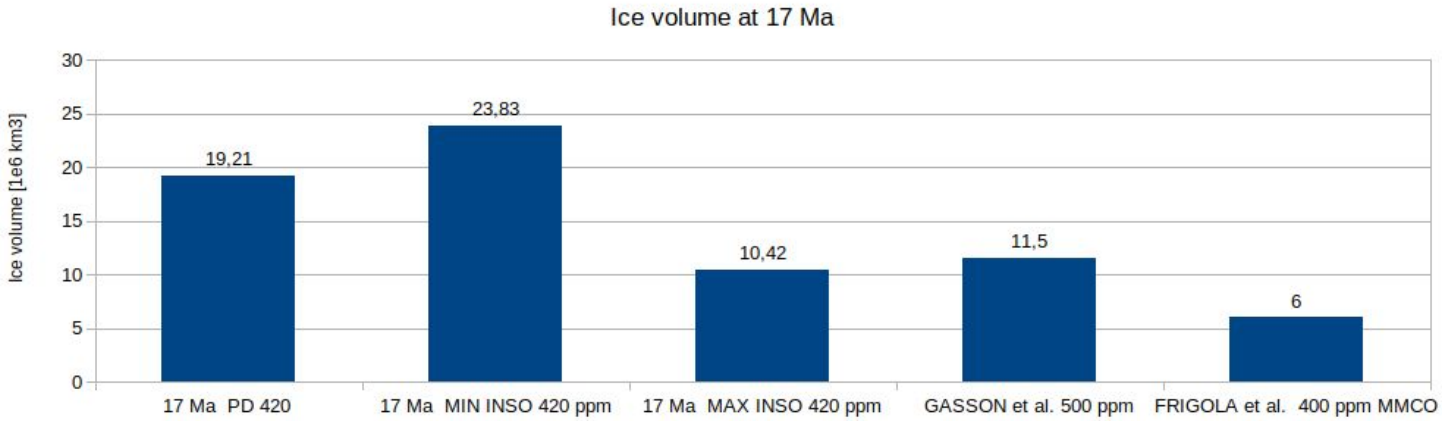
the most sensitive

- 14 Ma 420 ppm
  - insolation not impacting
    - climate colder to not let the ablation, AIS in equilibrium
- 17 Ma 420 ppm
  - really marked
    - warm enough to remove a big part of AIS

CONCLUSION

➔ “Consistency” with an indicative comparison with others studies as :

- Gasson et al. (2016) and Frigola et al. (2018)
- 17 Ma : strong variability but in the same range



Frigola, A., Prange, M., and Schulz, M.: Boundary conditions for the Middle Miocene Climate Transition (MMCT v1.0), Geosci. Model Dev., 11, 1607–1626, ttps://doi.org/10.5194/gmd-11-1607-2018, 2018

Gasson, E., DeConto, R.M., Pollard, D. et al. (1 more author) (2016) Dynamic Antarctic ice sheet during the early to mid-Miocene. Proceedings of the National Academy of Sciences, 113 (13).https://doi.org/10.1073/pnas.1516130113


THANK YOU

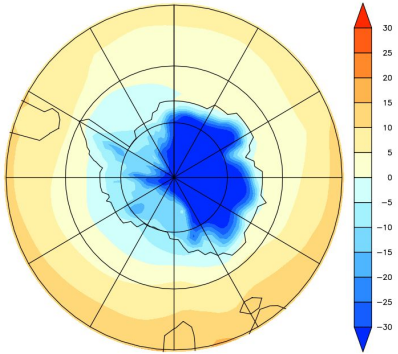
Additional slides

RESULTS IPSL OUTPUTS

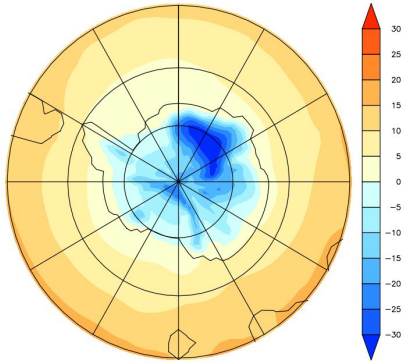
CLIMATOLOGICAL

- Compared to others studies and proxies
- 17 Ma 700 ppm : warm, humid

14 Ma min inso

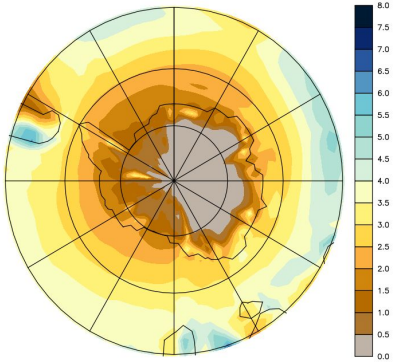


17 Ma max inso

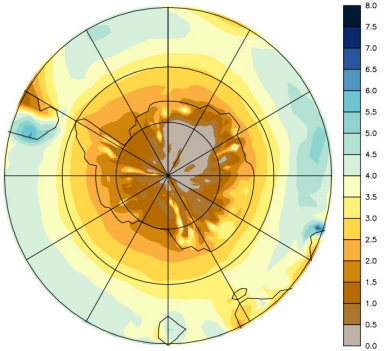


Mean annual temperature [°C]

14 Ma min inso



17 Ma max inso



Mean annual precipitations [mm/day]

impacts of the BC ⇨

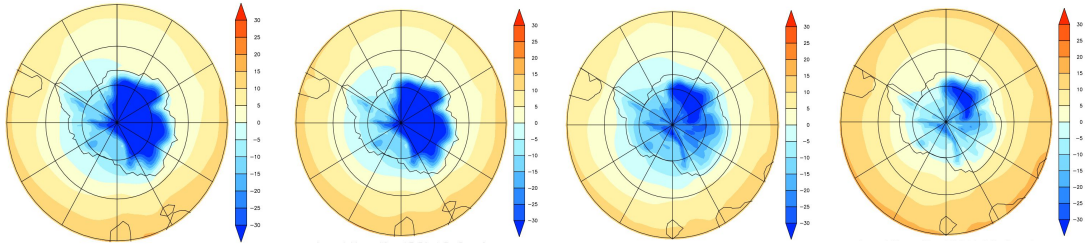
paleotopography
pCO2
insolation

Results IPSLCM5A2 -YELMO outputs

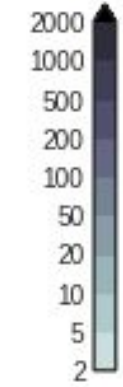
Forcings impact : **insolation**

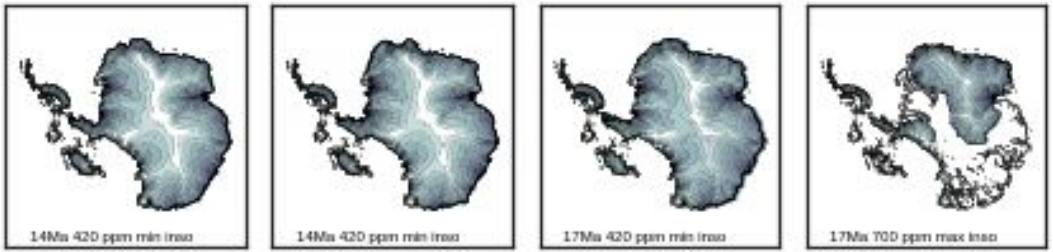
14 Ma 420 ppm		17 Ma 420 ppm	17 Ma 700 ppm
MIN insolation	MAX insolation	MIN insolation	MAX insolation

Mean annual temperature [°C]



Ice Velocity [m/yr]



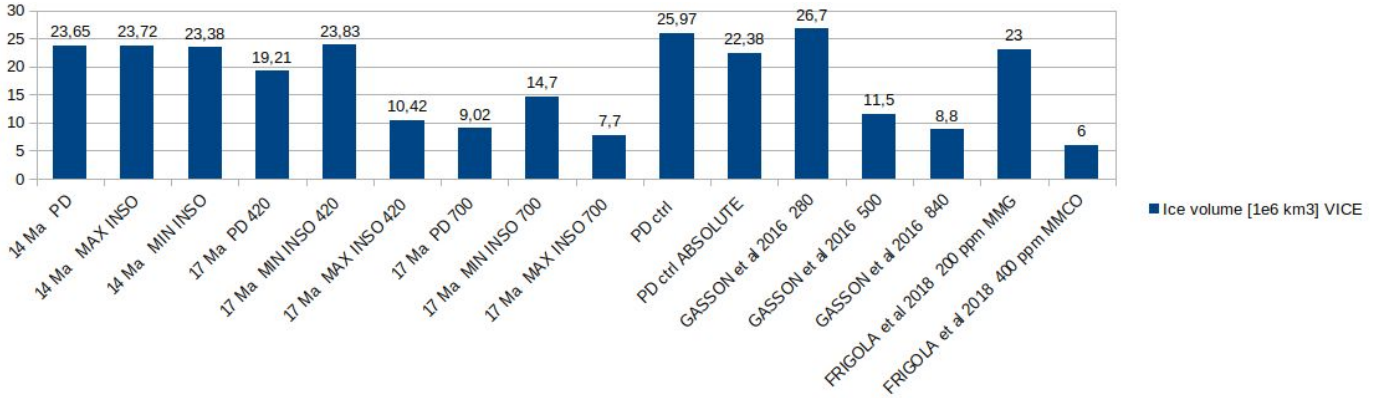


- 14 Ma 420 ppm
  - ➢ insolation not relevant
    - climate colder to not let the ablation

- 17 Ma + pCO2
  - ➢ really marked
    - warm enough to remove a big part of AIS

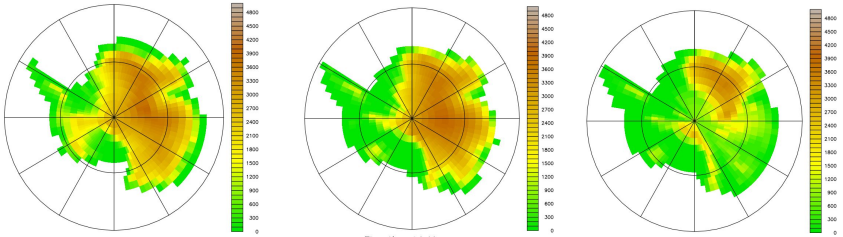
CONCLUSION

➔ Consistency of our results compared to others studies as Gasson et al in 2016 and Frigola et al in 2018



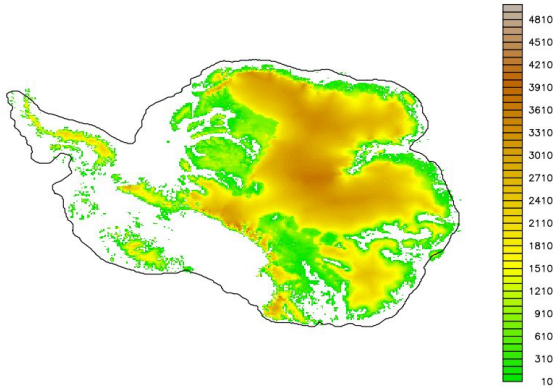
RESULTS YELMO OUTPUTS

Topographies in IPSL CM5A2



piCtrl Run | 14 Ma | 17 Ma

Topography 14 Ma in YELMO



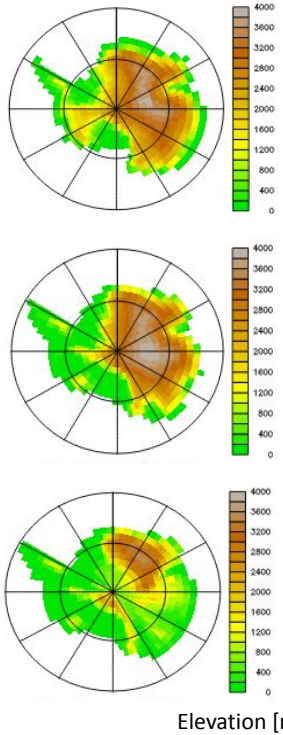
Volume of ice in Antarctica :

- Today : ~ **26,5 1e6** km3
- Miocene in IPSL :
  - 14 Ma 420 ppm : (~80 % PD) = **21,2 1e6** km3
  - 17 Ma 700 ppm : (~50 % PD) = **13,25 1e6** km3
- Miocene in YELMO:
  - 14 Ma 420 ppm = **20,71 1e6** km3
  - 17 Ma 700 ppm = **5,508 1e6** km3

Sensitivity experiments

IPSL CM5A2

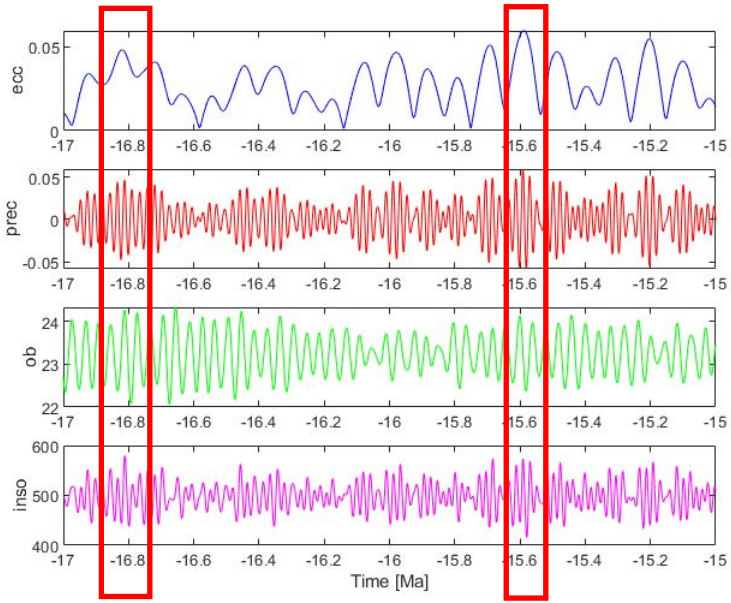
Variations in paleogeographies



Variations in pCO2

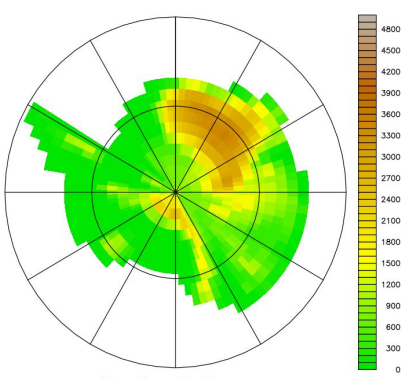
420 ppm
700 ppm

Variations in insolation

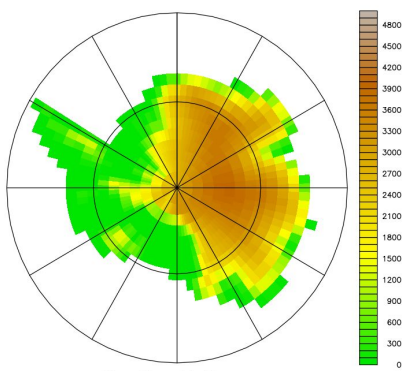


Forcing orbital parameters when INSO = MAX & MIN

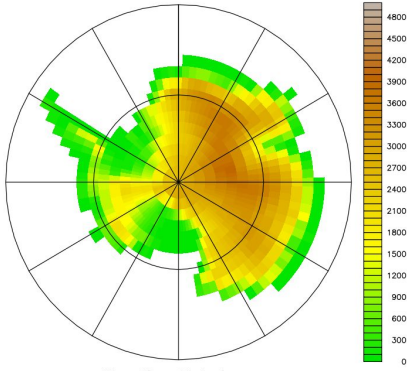
Topographies



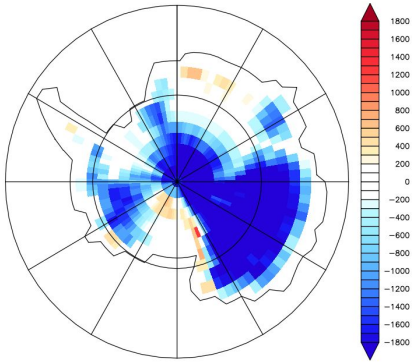
Elevation 17 Ma [m]



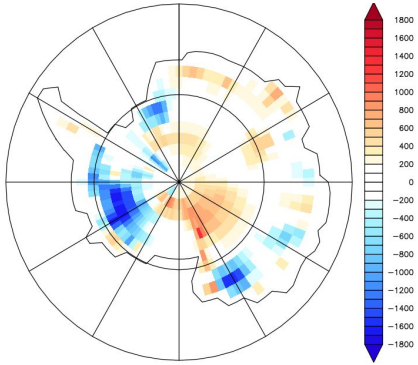
Elevation 14 Ma [m]



Elevation Ctrl PI [m]



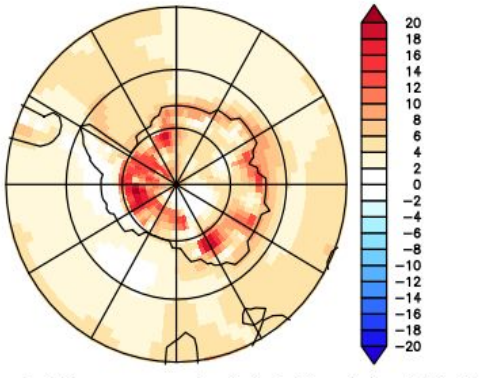
Topography anomaly 17 Ma –Ctrl PI [m]



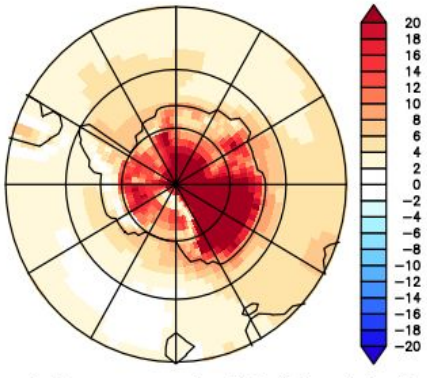
Topography anomaly 14 Ma –Ctrl PI [m]

Mean Annual Temperature Anomalies [°C]

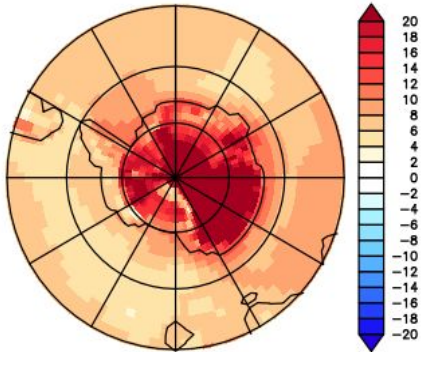
Paleotopographies effect



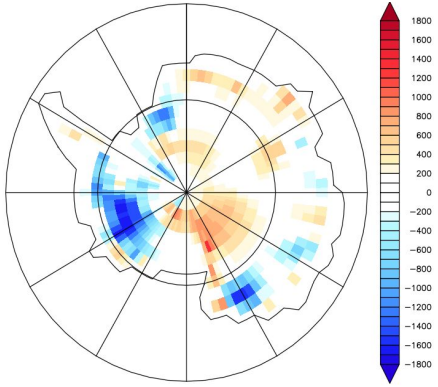
14 Ma 420 ppm – Ctrl PI



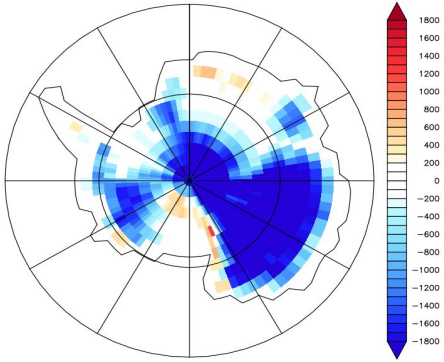
17 Ma 420 ppm – Ctrl PI



17 Ma 700 ppm – Ctrl PI



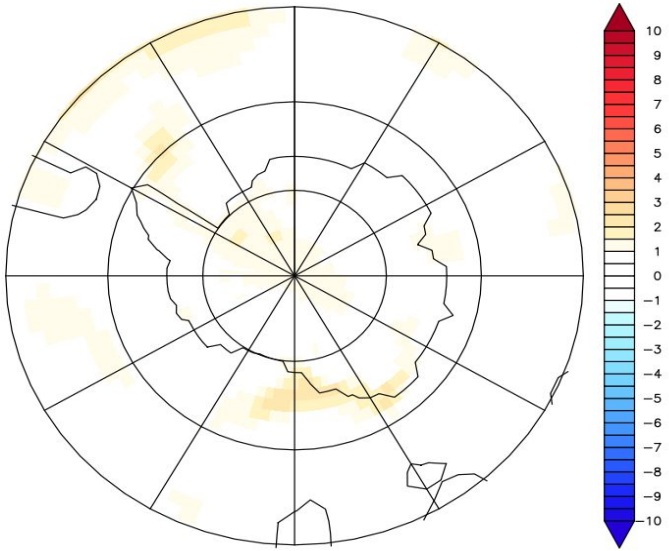
Topography anomaly 14 Ma –Ctrl PI [m]



Topography anomaly 17 Ma –Ctrl PI [m]

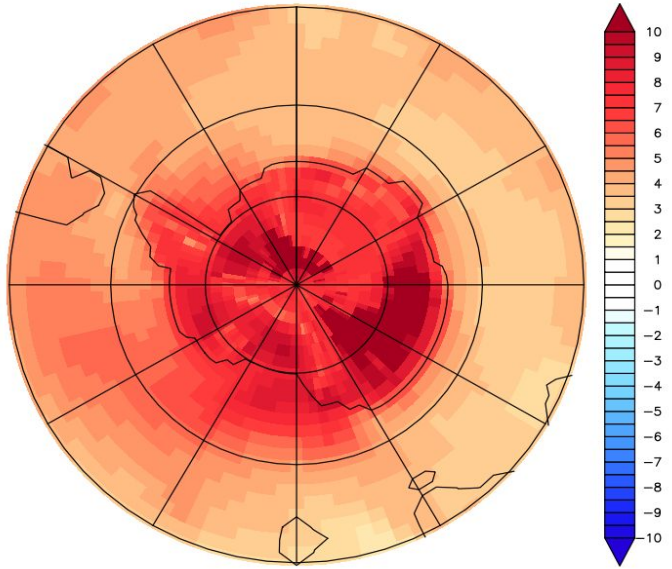
Mean Annual Temperature Anomalies [°C]

insolation effect



14 Ma 420 ppm
Max-Min insolation

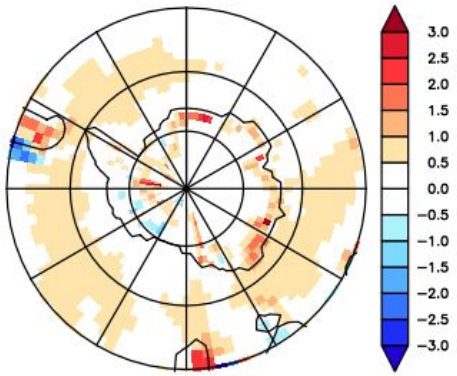
pCO2 + insolation effect



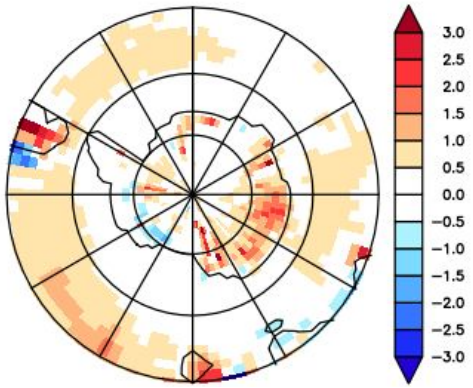
17 Ma 700 ppm-420 ppm
Max-Min insolation

Mean Annual Precipitation anomalies [mm/d]

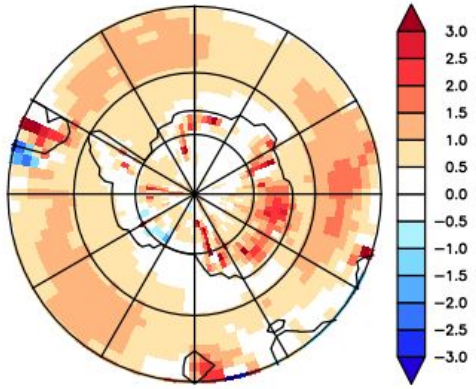
Paleotopographies effect



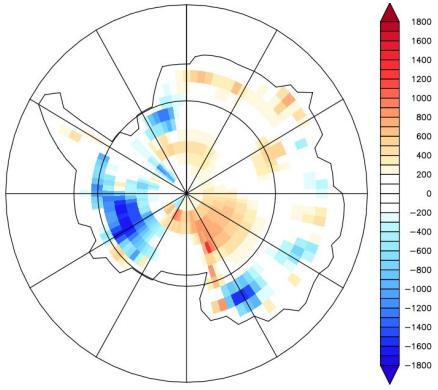
14 Ma 420 ppm – Ctrl PI



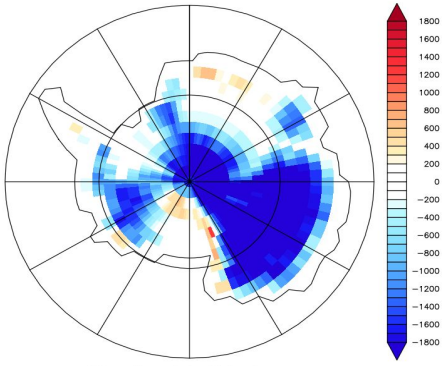
17 Ma 420 ppm – Ctrl PI



17 Ma 700 ppm – Ctrl PI



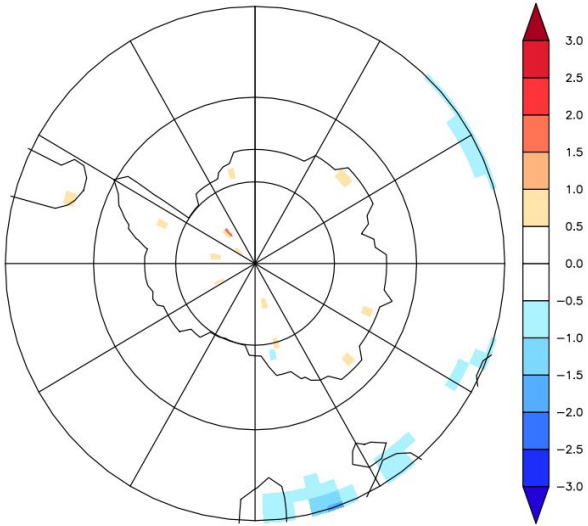
Topography anomaly 14 Ma –Ctrl PI [m]



Topography anomaly 17 Ma –Ctrl PI [m]

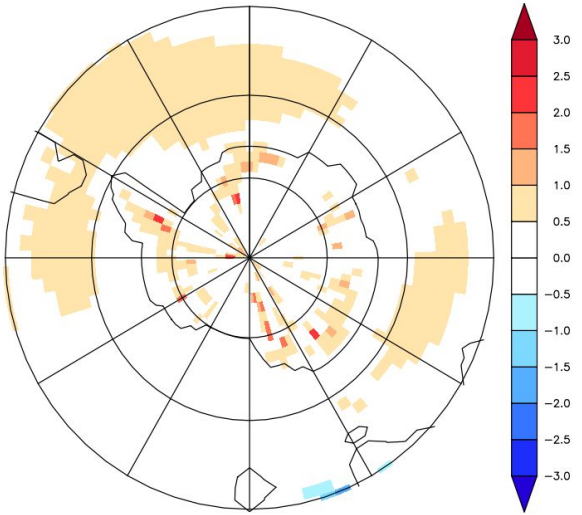
Mean Annual Precipitation Anomalies [mm/d]

insolation effect



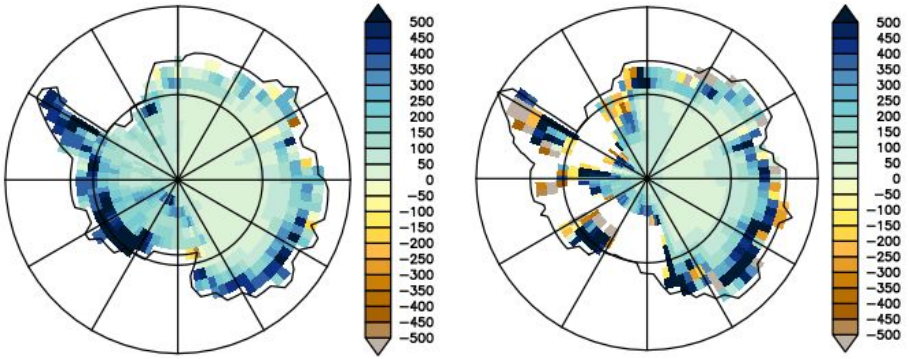
14 Ma 420 ppm
Max-Min insolation

pCO2 + insolation effect



17 Ma 700 ppm-420 ppm
Max-Min insolation

Surface Mass Balance (SMB) [mm/yr]



Ctrl PI 280 ppm

14 Ma 420 ppm

From Thompson & Pollard 1997

✔ Part of rainfall and meltwater [0;1] refereezing

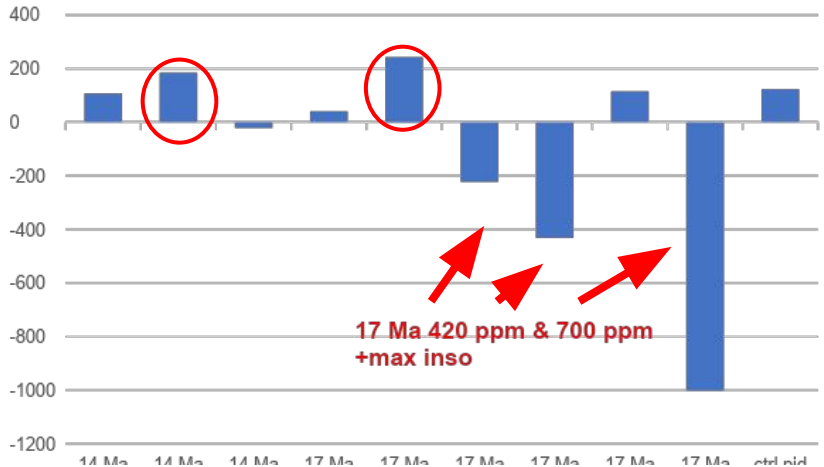
- Topography effect
- 17 Ma + high pCO2 : lots of ablation

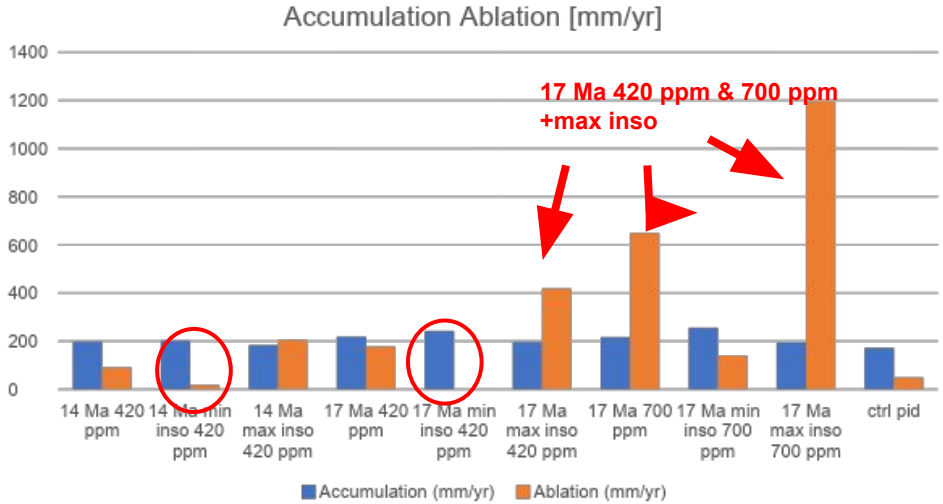
17 Ma 420 ppm

17 Ma 700 ppm

SMB, ablation & accumulation

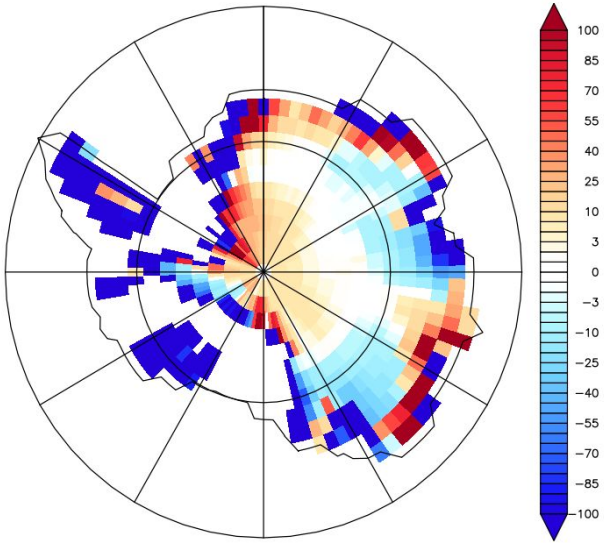
17 Ma + low margins + warm climate } SMB < 0
ablation > accumulation





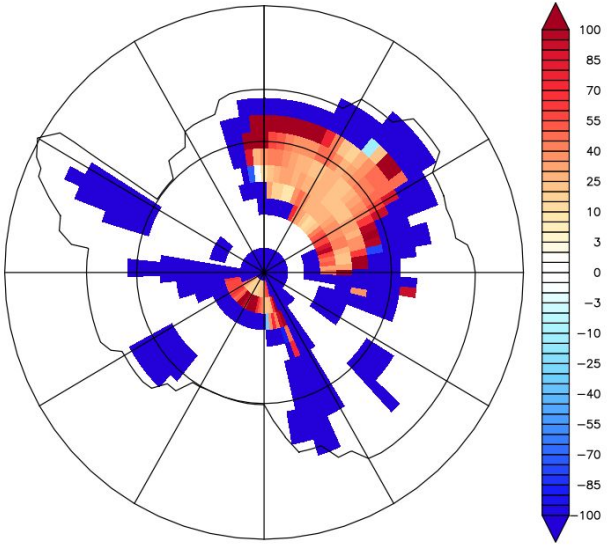
SMB anomalies [mm/yr]

insolation effect



14 Ma 420 ppm
Max-Min insolation

pCO2 + insolation effect



17 Ma 700 ppm-420 ppm
Max-Min insolation

Conclusion

- 14 Ma 420 ppm and 17 Ma 420 ppm ≡ Ctrl PI
- At 17 Ma and margins : SMB very negative

⟹ AIS impacted by topography pCO2 insolation variabilities

Conclusion

AIS at 17 Ma : very instable because of

- 700 ppm pCO2
- Max insolation

At 17 Ma , coupled with an ice sheet model can be a **problem**, topography prescribed is maybe too small

Summary of the main prescribed forcing factors for all numerical experiments

Model	Experiments x 16	Topography	pCO2	Orbital parameters	Ice Sheet	Bathymetry	Vegetation
IPSL CM5A2	Miocene reference x3	Frigola et al 2018 + changes	420 ppm & 700 ppm	PD orbit	700 ppm : small (~50% of today's AIS) 420 ppm : large (~80% of today's AIS)	Muller et al 2008 + changes	PlioMIP2 prescribed Contoux et al 2012
	Sensitivity to forcings x6	Frigola et al 2018 + changes		Max & Min insolation at 75°S in summer			
	No Ice Sheet x6	Straume et al 2020		Warm & Cold orbi	no ice sheet prescribed		PlioMIP , 20% of 5 main PFT mixed in each grid cell
	PD Ctrl x1	Sepulchre et al 2020	280 ppm	PD orbit	PD	Sepulchre et al 2020	Sepulchre et al 2020