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Climate Dynamics
February 2013

Influence of Antarctic ice sheet lowering on the Southern Hemisphere climate: modeling experiments mimicking the mid-Miocene

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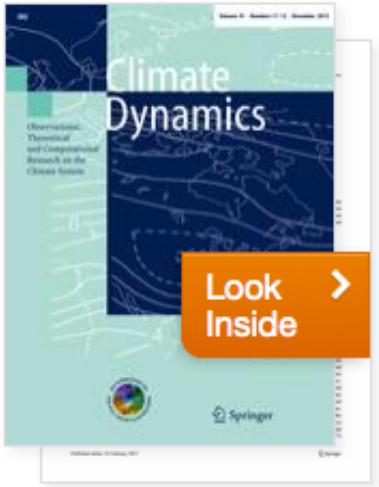

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Abstract

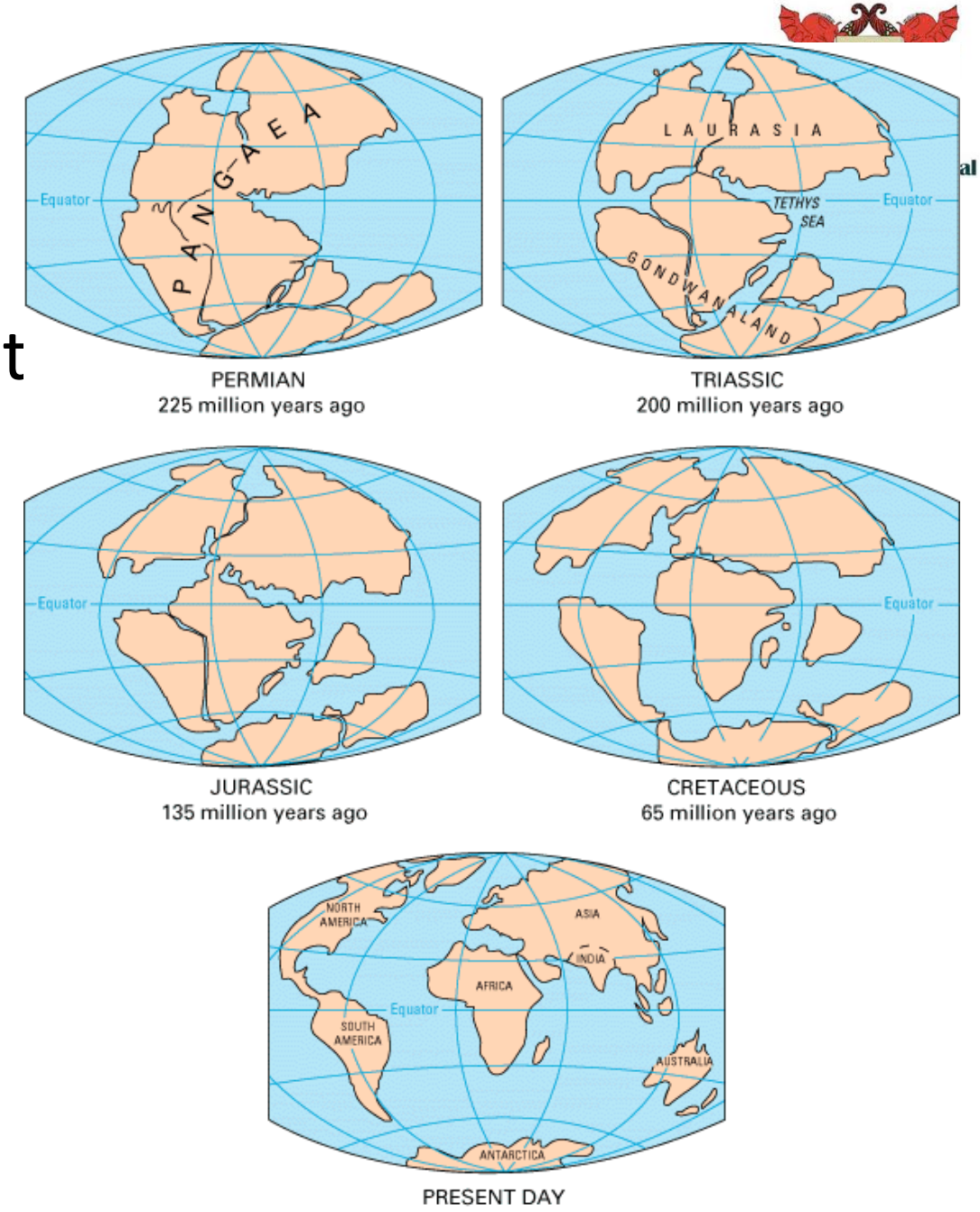
A coupled global atmosphere-ocean model is used to study the influence of the Antarctica ice sheet in a configuration that mimics that of the early Miocene on the atmospheric and oceanic circulations. Based on different climate simulations of the present day (CTR) and conducted with distinct Antarctic ice sheet topography (AIS-EXP), it is found that the reduction of the Antarctic ice sheet topography (AIS) induces warming of the Southern Hemisphere and reduces the meridional thermal gradient. Consequently, the atmospheric transient low level eddy heat flux $[\overline{(v'T')}]$ and the eddy momentum flux $[\overline{(u'v')}]$ are reduced causing the reduced transport of heat from the mid-latitudes to the pole. The stationary flow and transient wave anomalies generate changes in the SSTs which modify the rate of deep water formation, strengthening the formation of the Antarctic Bottom Water. Substantial changes are predicted to occur in the atmospheric and oceanic heat

Share

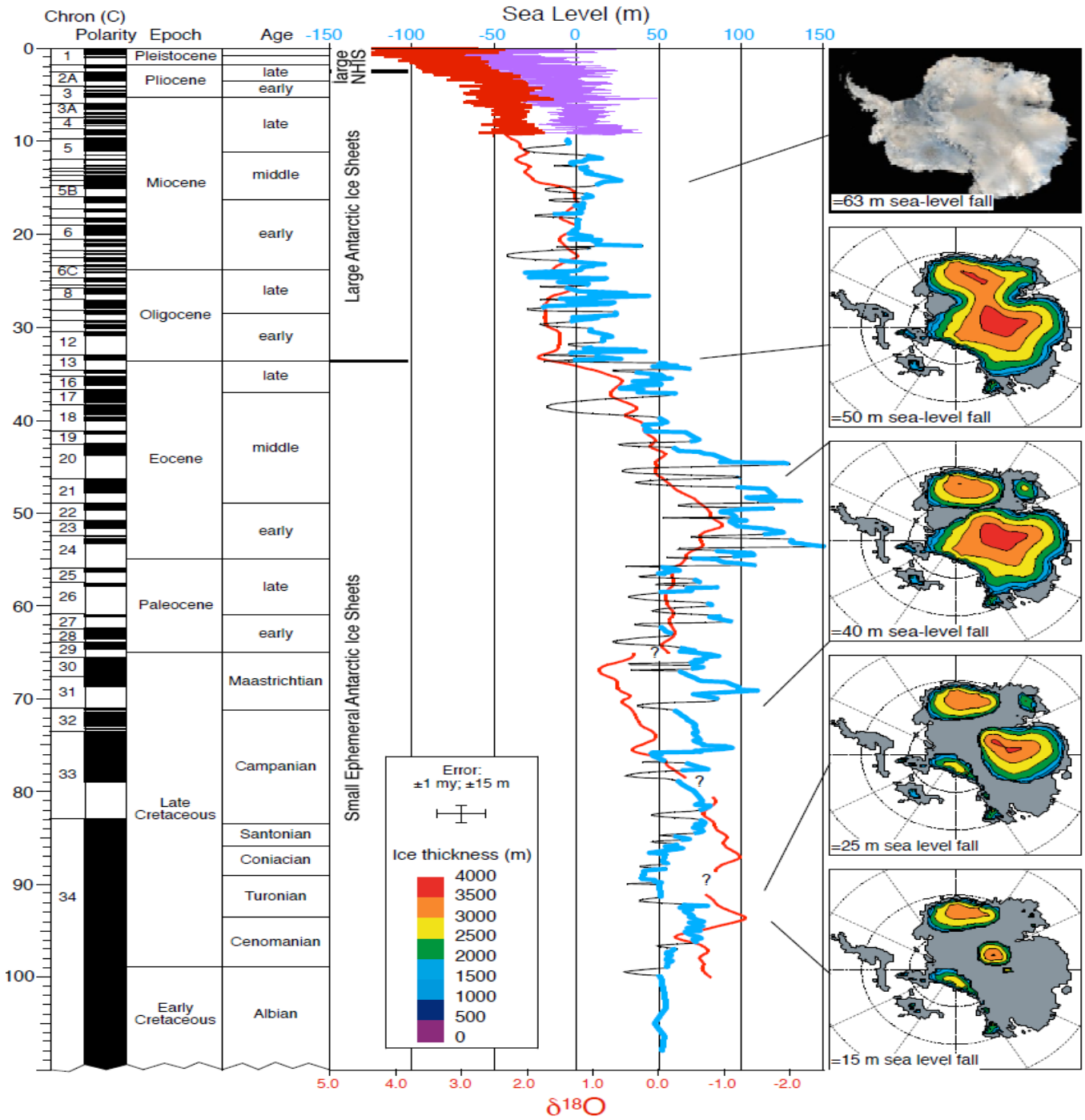
Introduction

- Antarctica has varied substantially in the Earth's climate history
- During the early Miocene (23-17 Ma), as suggested by records from the Ocean Drilling Program (ODP), the ice sheet volume has been about 50%-125% of the present-day values.
- WAIS collapsed during the MIS31 (1.08My)
- WAIS collapses in GHG projections.

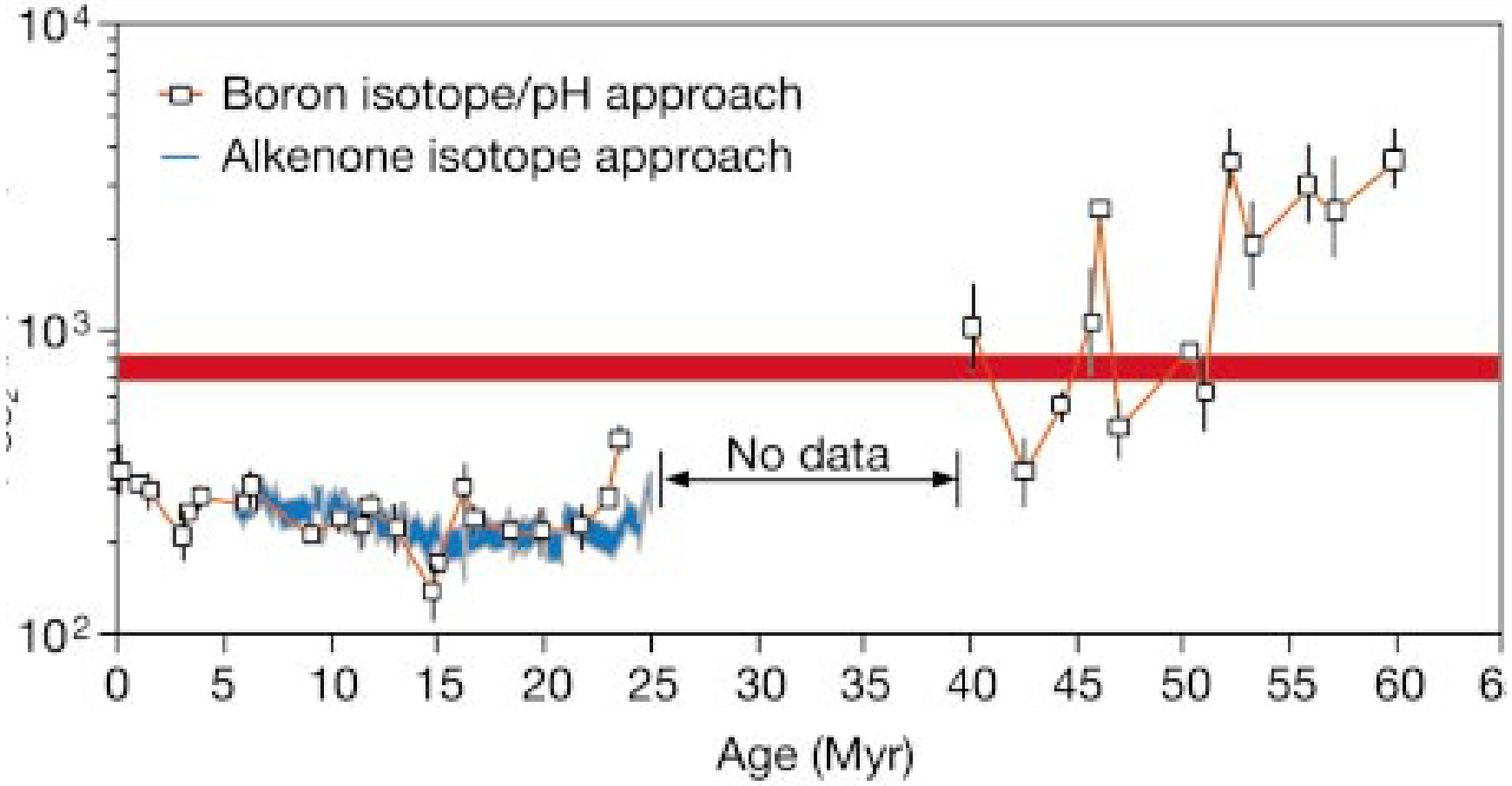
- Antarctic Ice Sheet
- Evolution



- Sea Level evolution

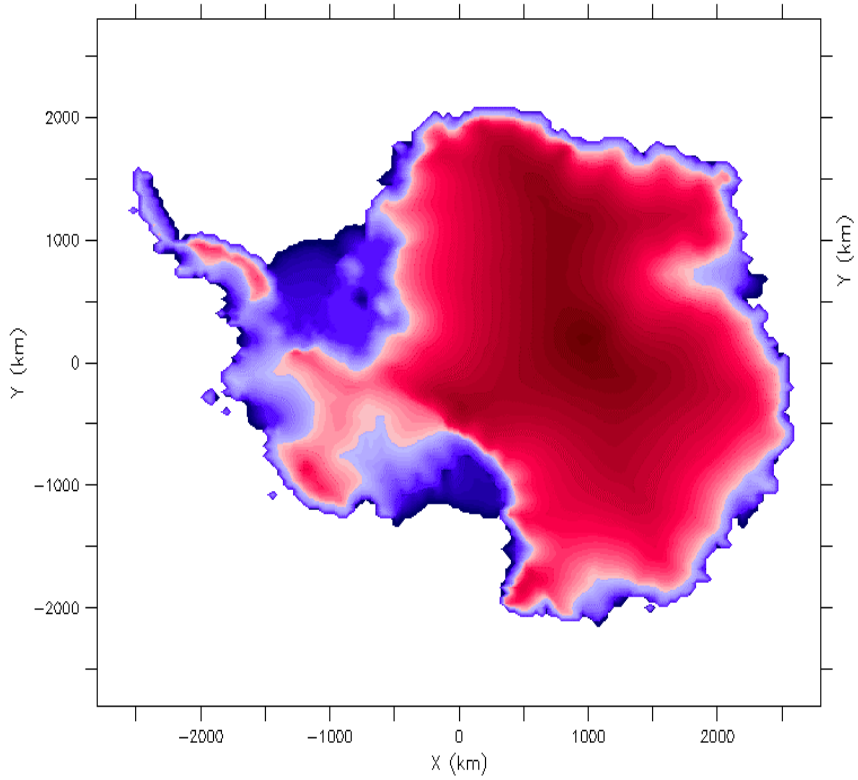


CO2 Effect

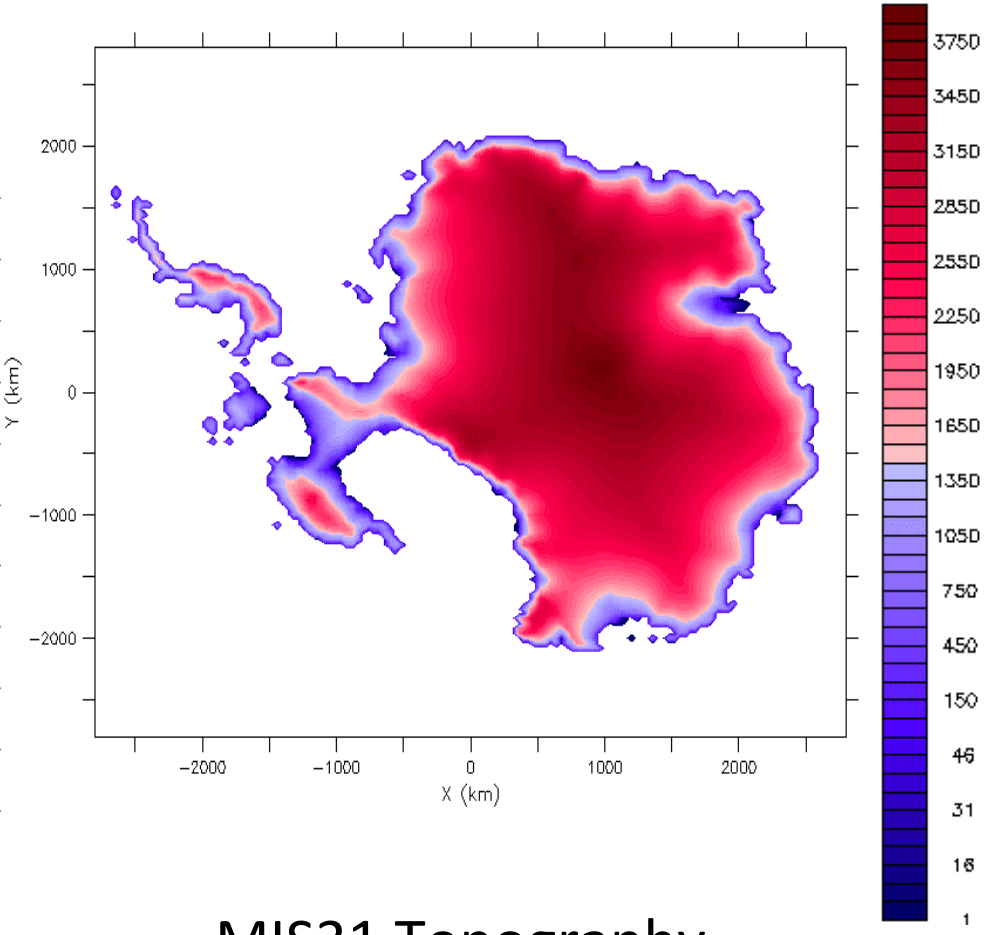


DeConto and Pollard 2003

AIS topography



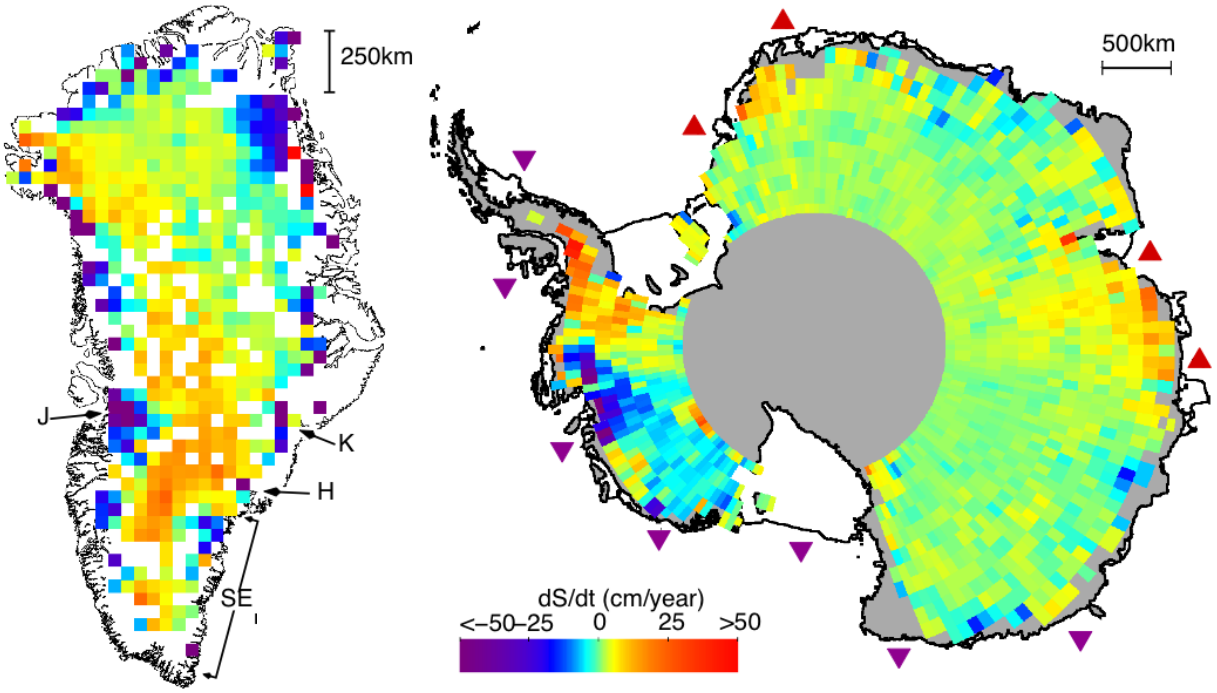
Present day (CTR)



MIS31 Topography

IPCC

- Ice sheet mass balance

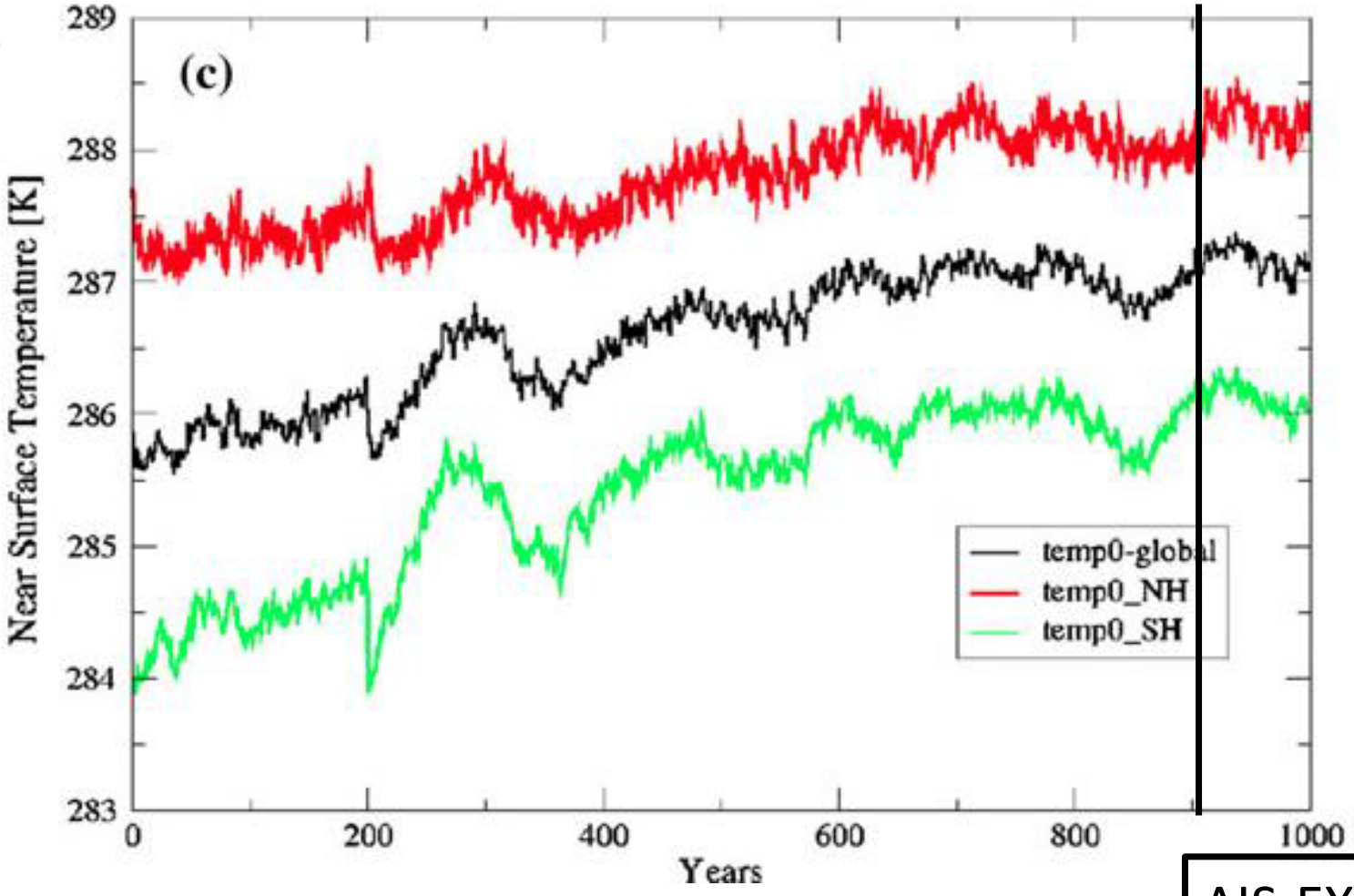


Model: SpeedO

- An EMIC; a 3D coupled atmosphere-ocean-sea ice general circulation model
- Atmospheric Component: Speedy; KNMI version of the Speedy model developed at the International Center for Theoretical Physics (ICTP)
- Oceanic Component: CLIO; a primitive equation, free-surface ocean general circulation model coupled to a thermodynamic-dynamic sea-ice model

Simulation periods	1000 years
Horizontal resolution Atmosphere	3.75° x 3.75°
Vertical resolution	8 layers
Horizontal resolution Ocean	3° x 3°
Vertical resolution	20 layers
Initial and boundary conditions	Pre-industrial
AIS height	CTR: current AIS-EXP: 25% lower

Near surface temperature
From present towards “MIS31”



AIS-EXP

Atmospheric impacts
Surface temperature

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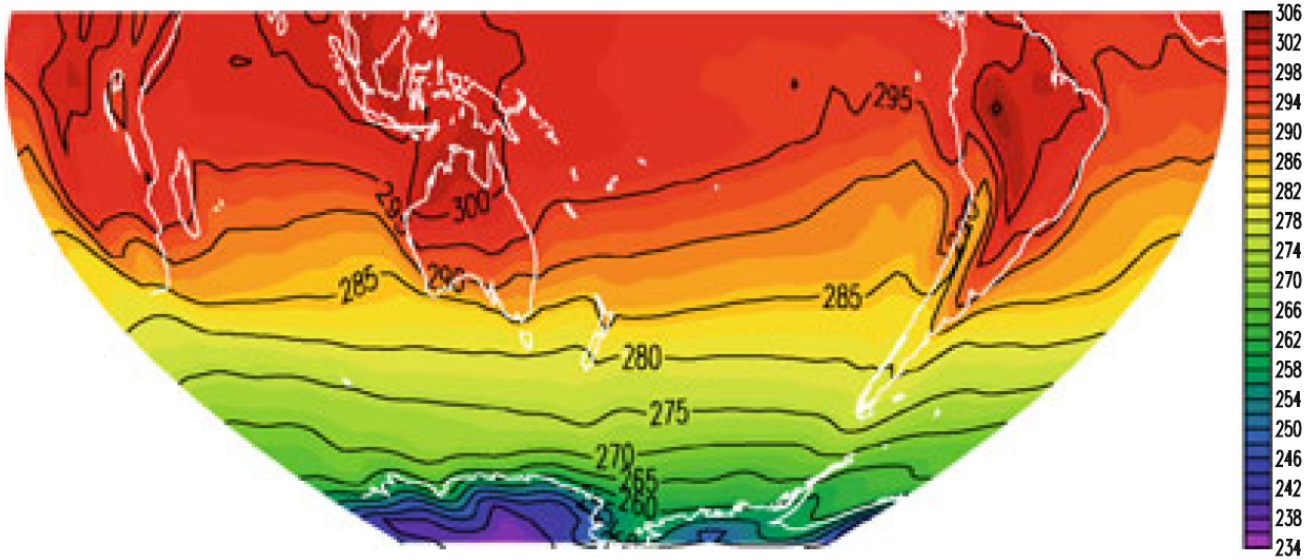
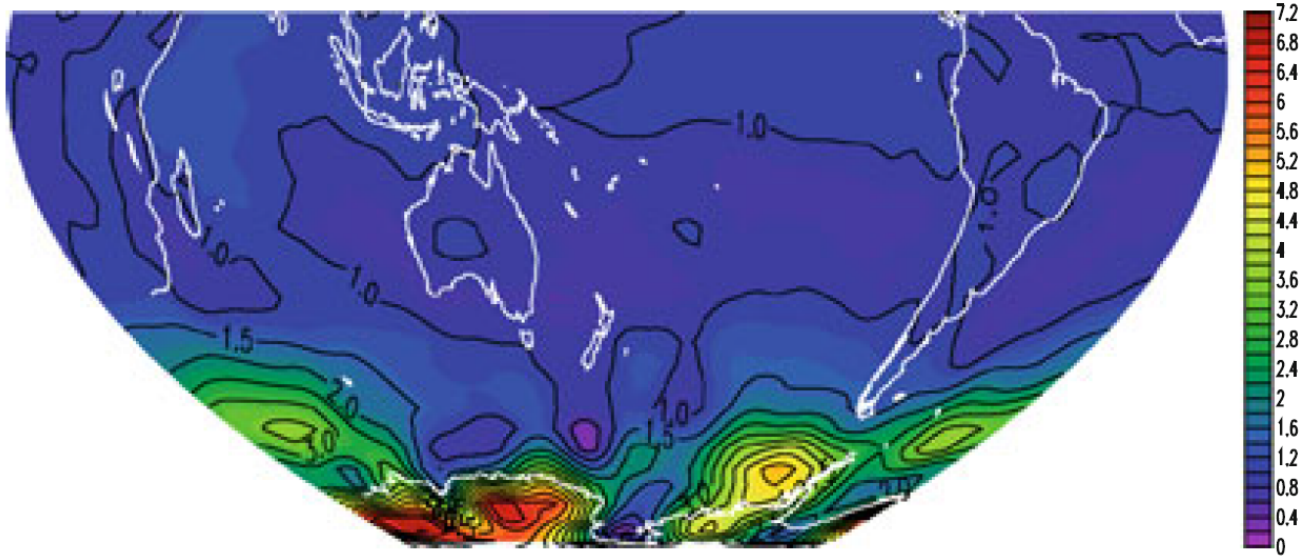
Present day

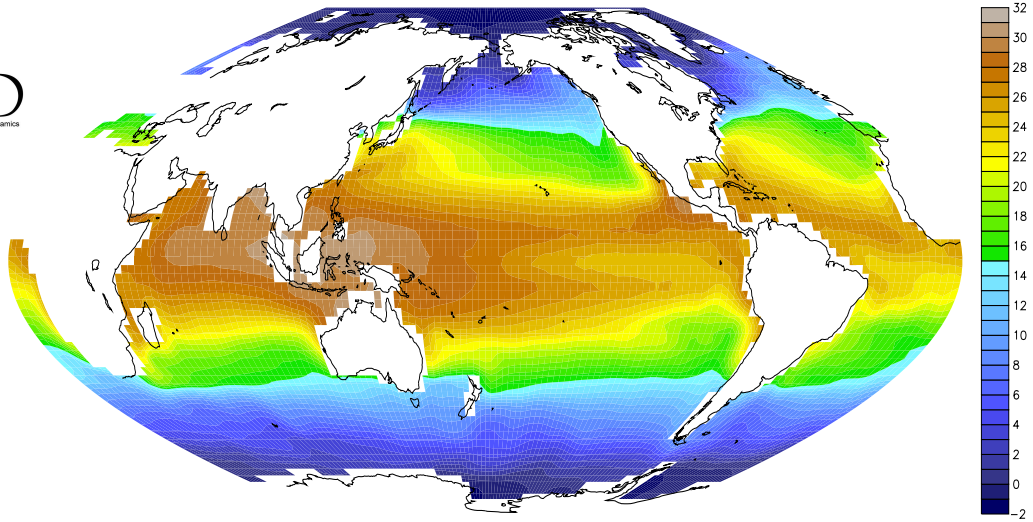


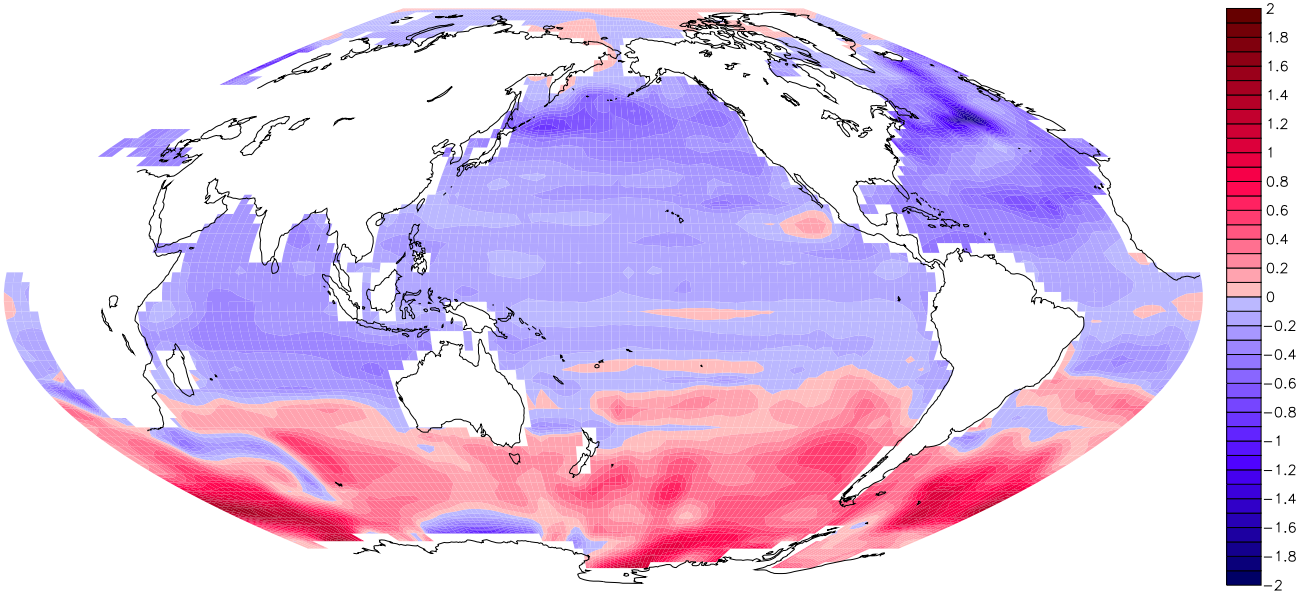
Anomaly

Polar heating:
Lapse rate &
Clouds/IR trap



SSTs


32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
−2

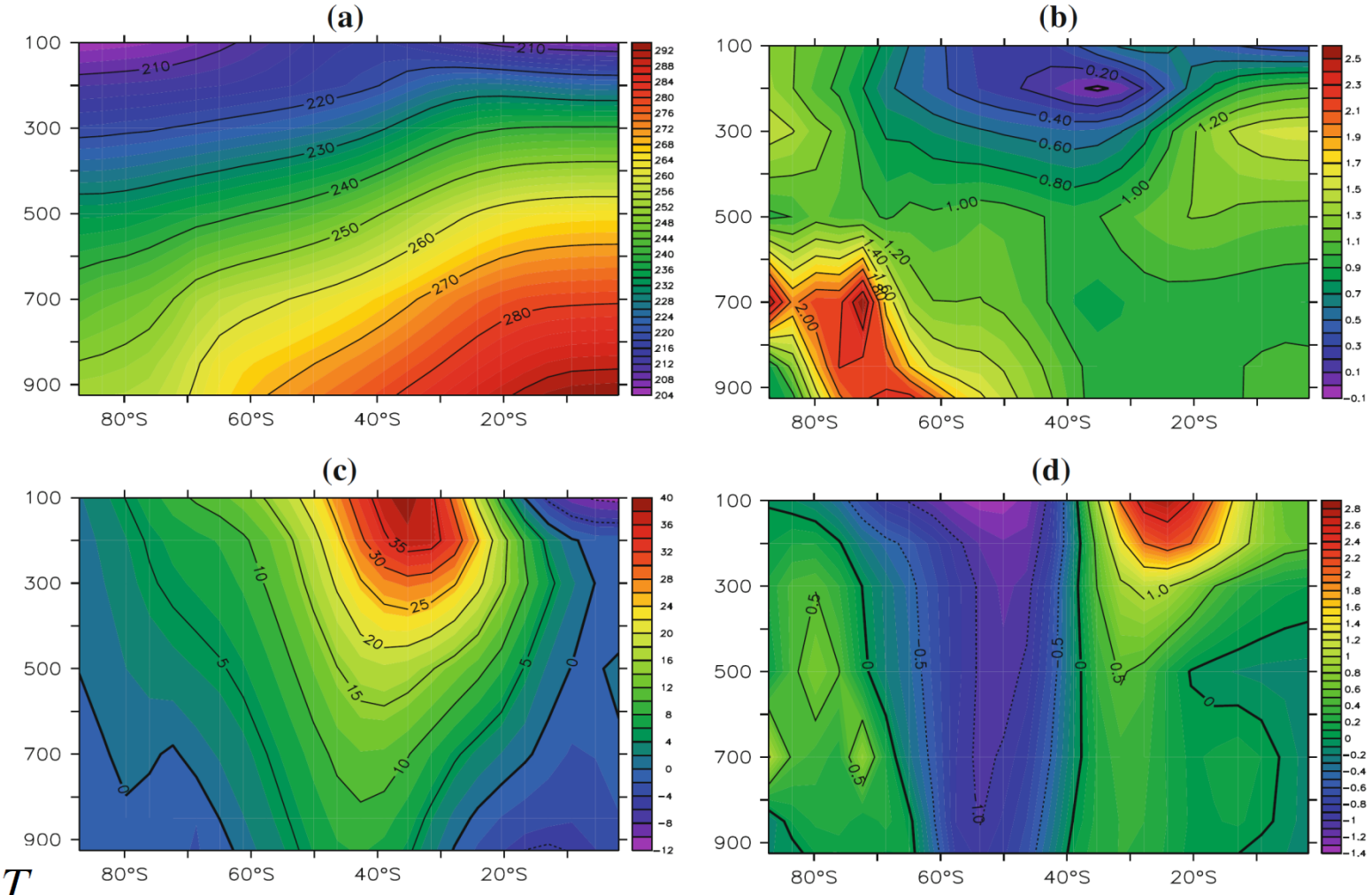

2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
−1.4
−1.6
−1.8
−2

Atmospheric impacts
Meridional T and zonal wind

T
Decrasing low level mid lat dT/dy

U
Decrasing mid lat westeries

$$\frac{\partial u_g}{\partial z} = -\frac{R}{fH}\frac{\partial T}{\partial y}$$



Present day

Anomaly

RESULTADOS

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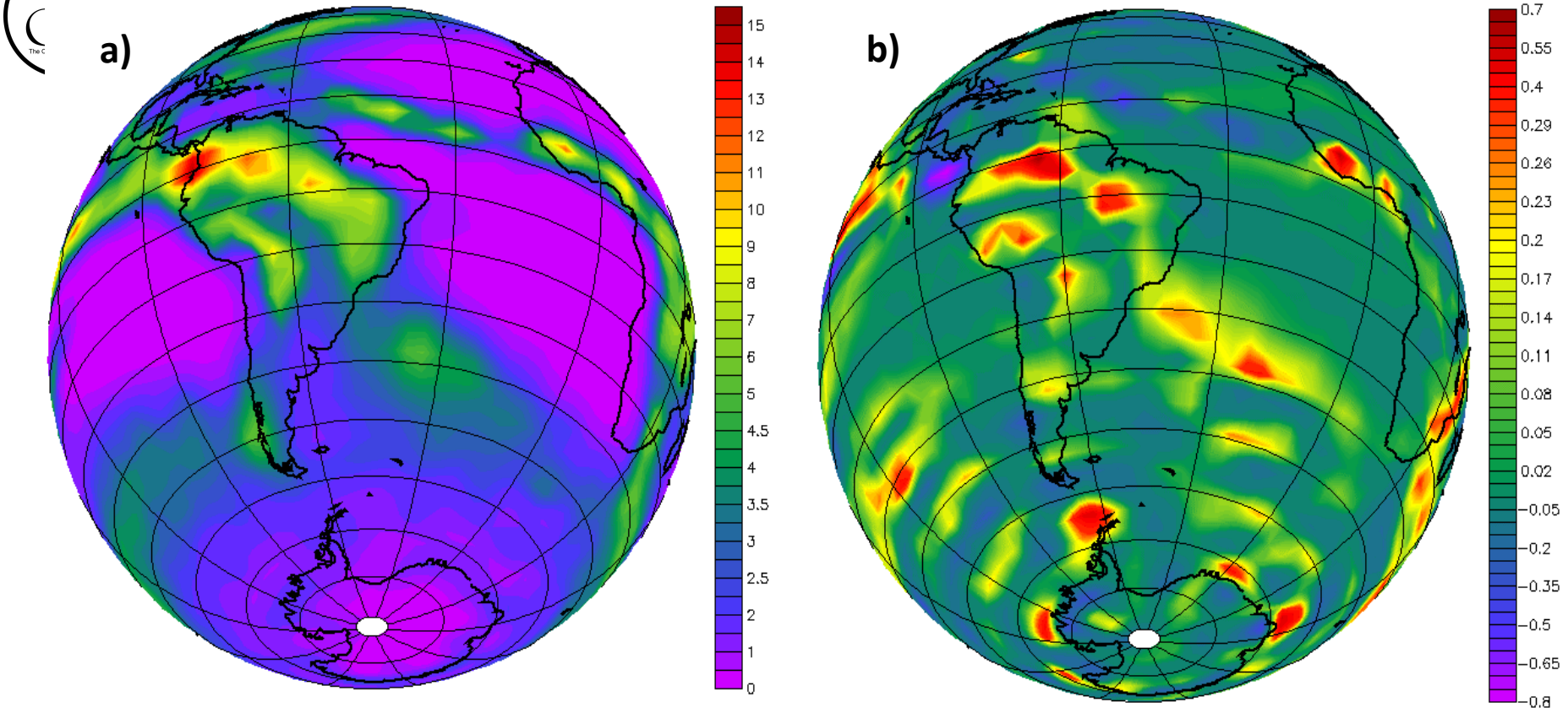
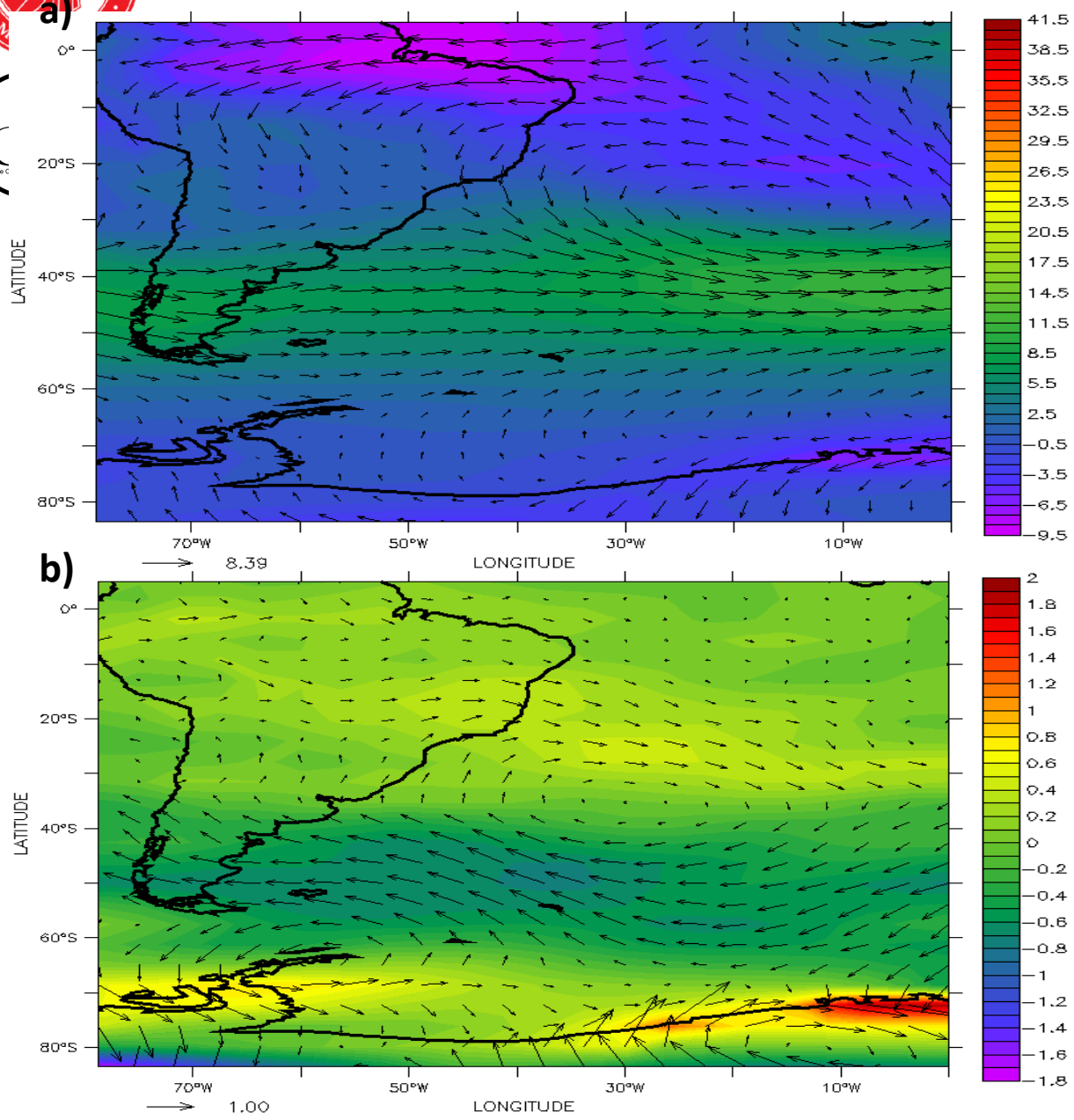


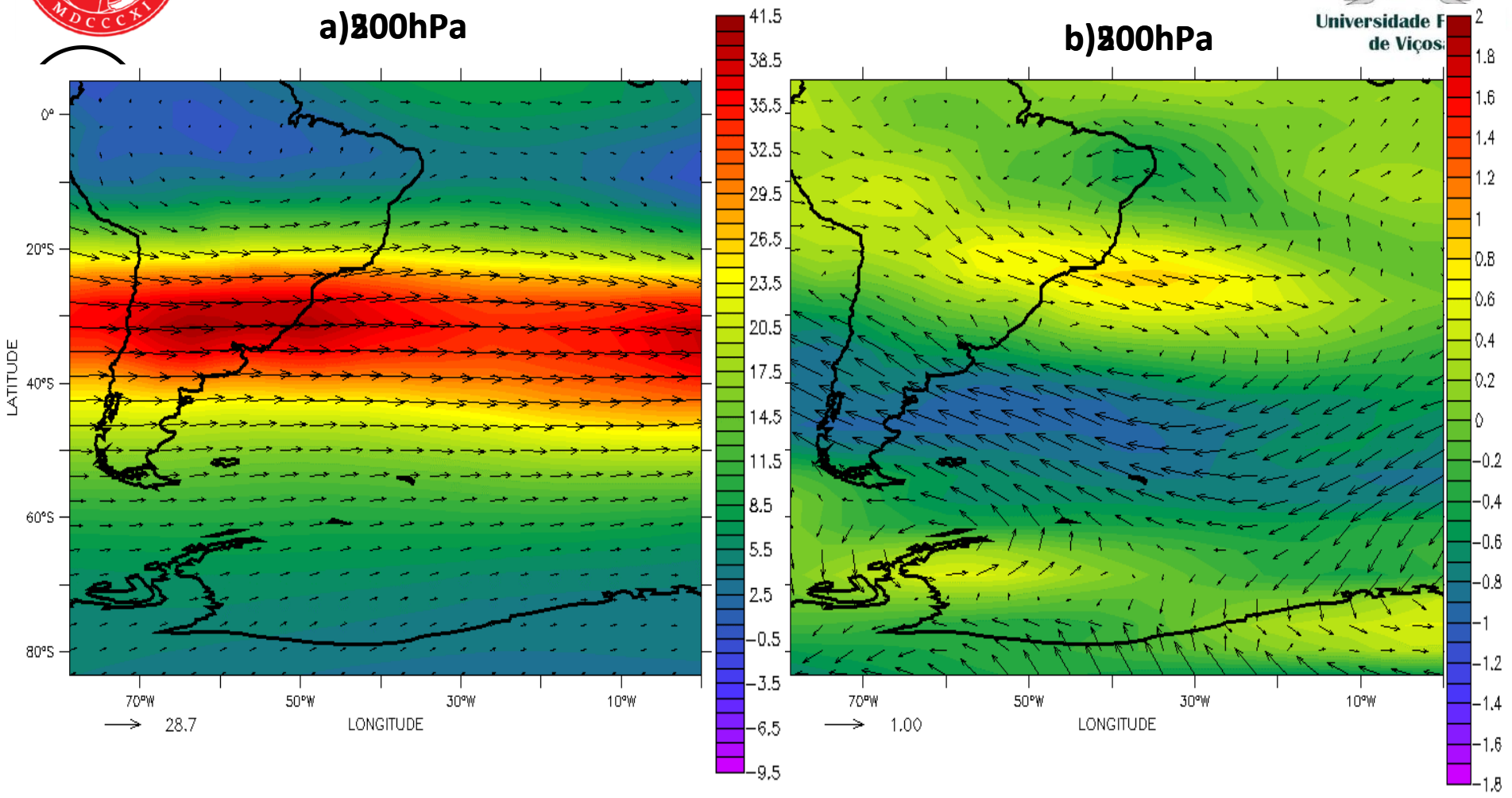
Mean Precipitation (*mm/day*). **(a)** *CTRL;* **(b)** 1080ka – CTRL .

RESULTADOS



Zonal wind ($m\ s^{-1}$), at 850hPa. **(a)** *CTRL*; **(b)** 1080ka - CTRL.

RESULTS


a) 200hPa
b) 200hPa
0°
20°S
40°S
60°S
80°S
LATITUDE
70°W
50°W
30°W
10°W
LONGITUDE
28.7
1.00
41.5
38.5
35.5
32.5
29.5
26.5
23.5
20.5
17.5
14.5
11.5
8.5
5.5
2.5
−0.5
−3.5
−6.5
−9.5
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
−1.4
−1.6
−1.8

Considerations

- These results fit nicely with the ODP 1090 and 1218 (e.g. Billups and Schrag [2002])
- ODP Site 745, the East Kerguelen sediment drift (Leah et al. 2002)

The South America Monsoon

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RECENT DEVELOPMENTS ON THE SOUTH AMERICAN MONSOON SYSTEM

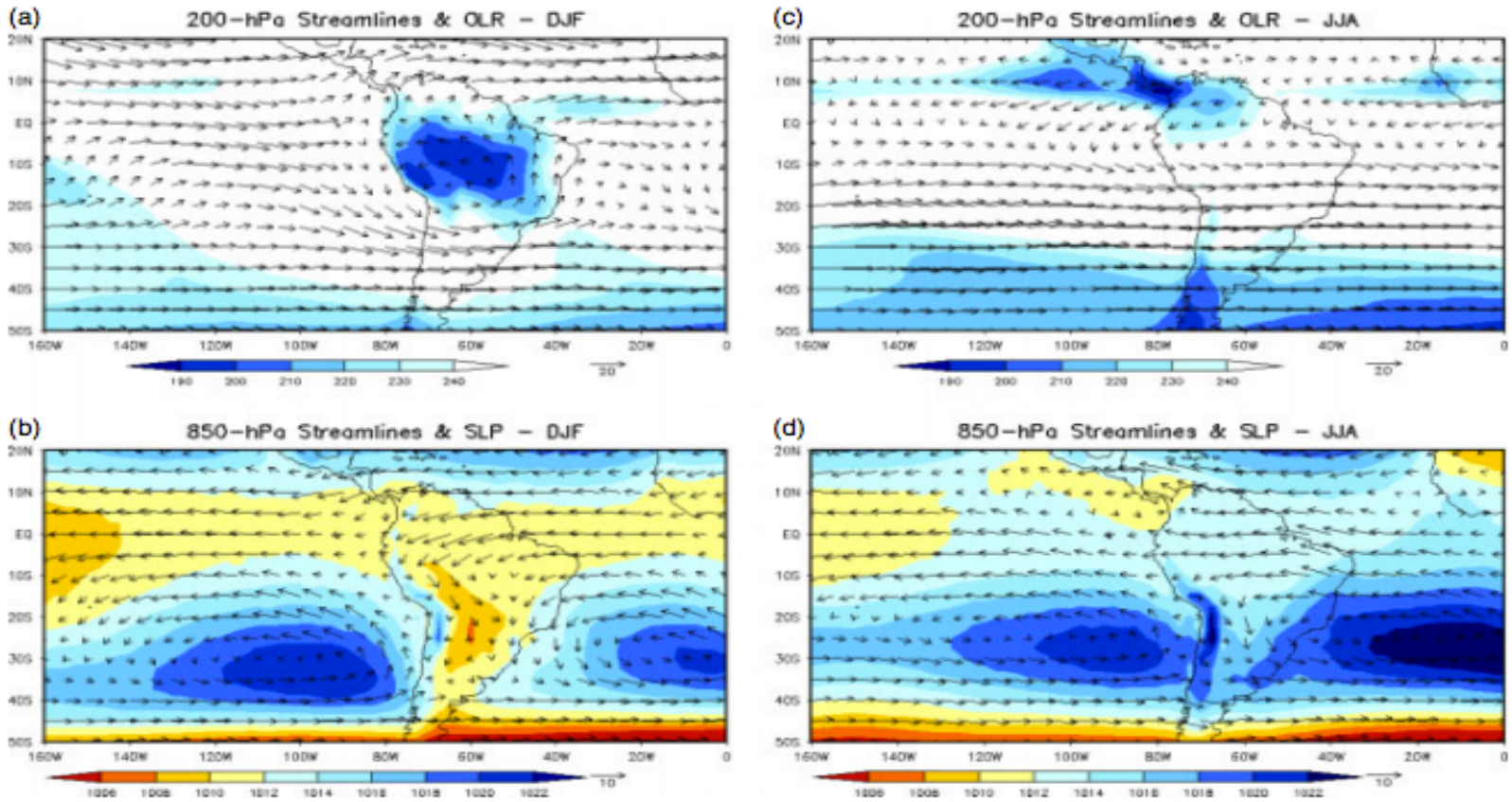
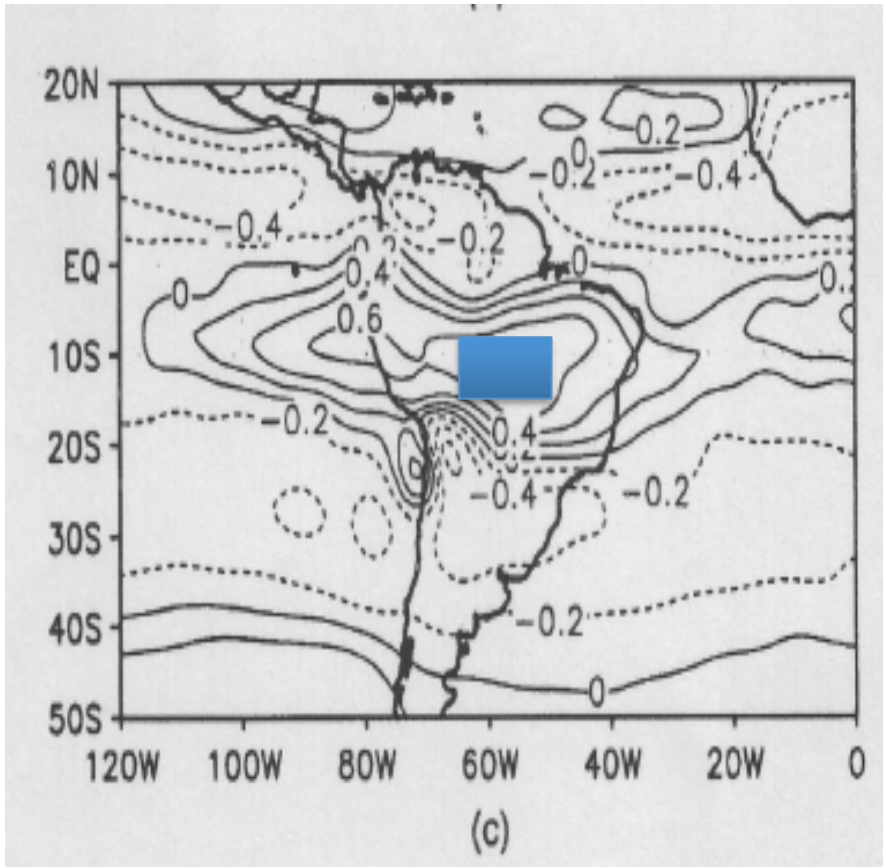


Figure 1. Mean (1979–2008) 200-hPa wind vector and outgoing longwave radiation (OLR) (top) and 850–hPa wind vector and sea level pressure (SLP) (bottom), for DJF and JJA. Units are W m-2 for OLR and hPa for SLP. Circulation data are derived from the NCEP/NCAR Reanalysis. This figure is available in colour online at wileyonlinelibrary.com/journal/joc

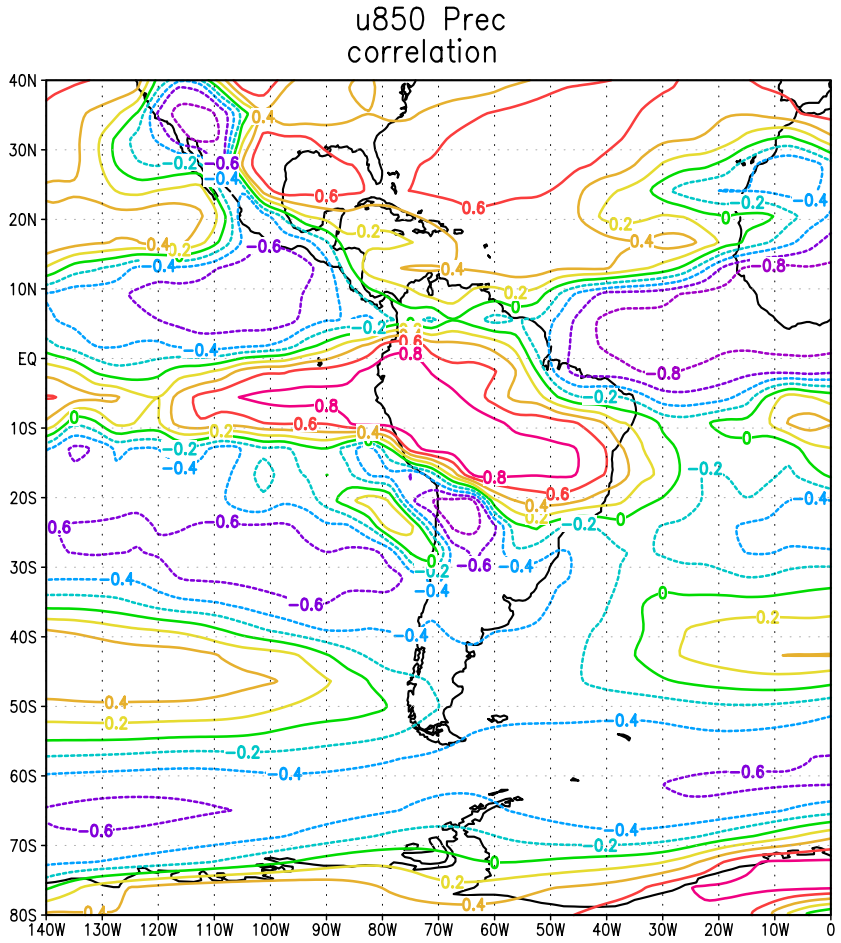
Marengo et al. 2010

SPEEDO x Observations

Zonal wind - Prec correlations

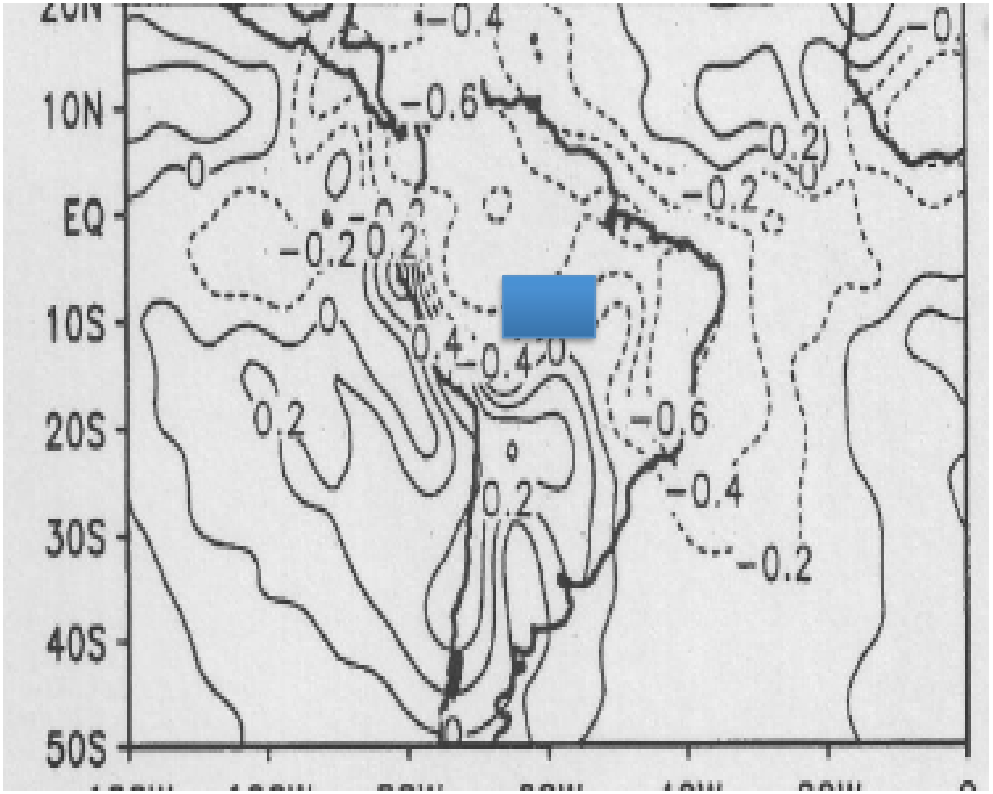


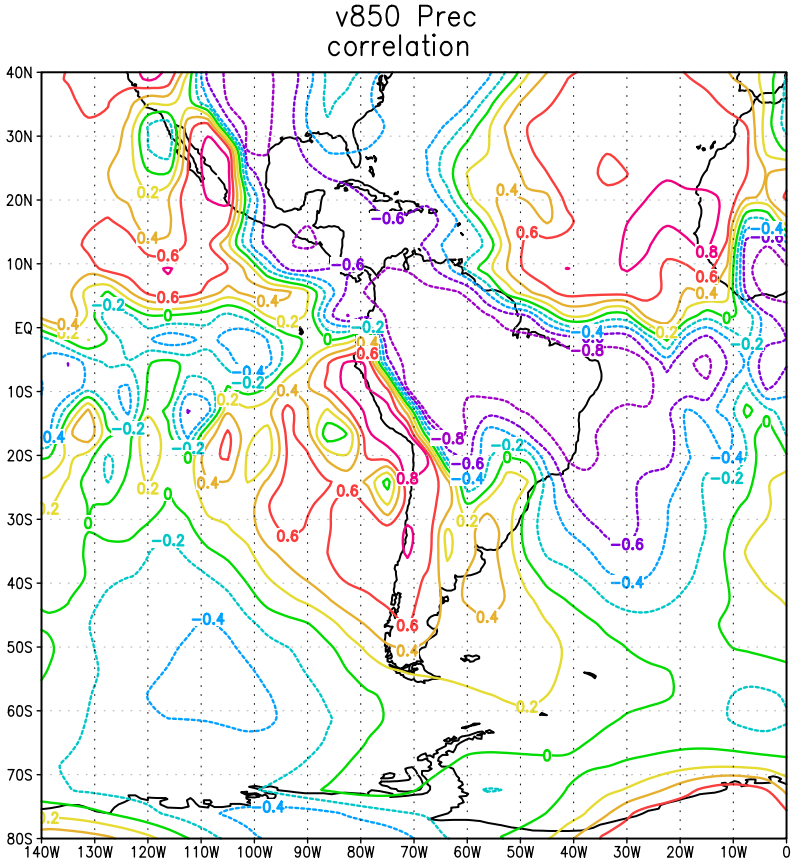
Gan et al (2004)



SPEEDO x Observations

Meridional wind - Prec correlations





Was the Paleo-SAM different?

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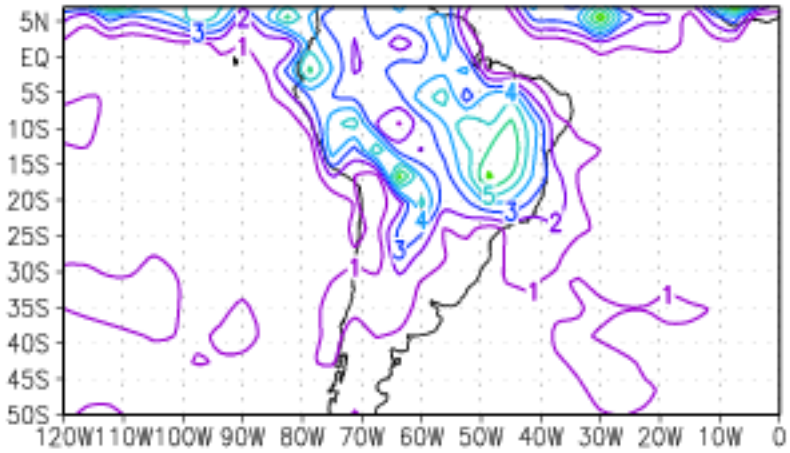
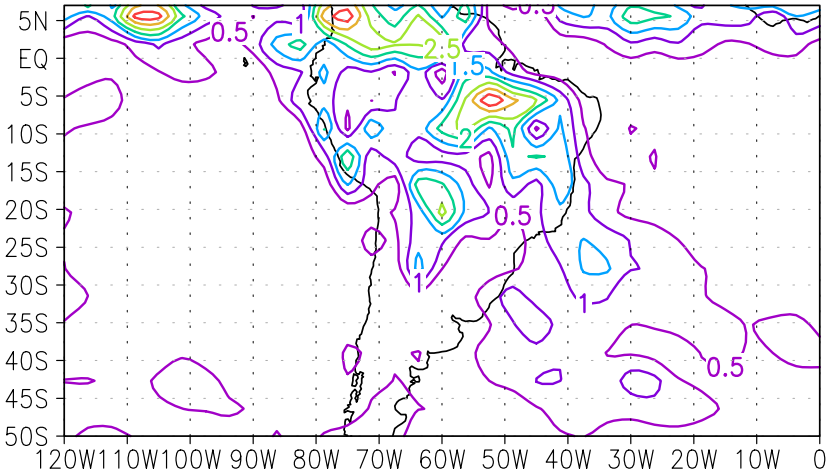
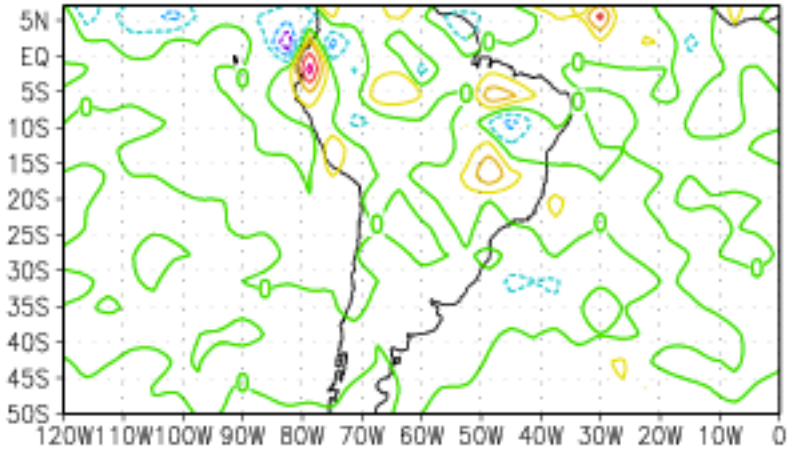
prec amp
1st Harmonic CTR



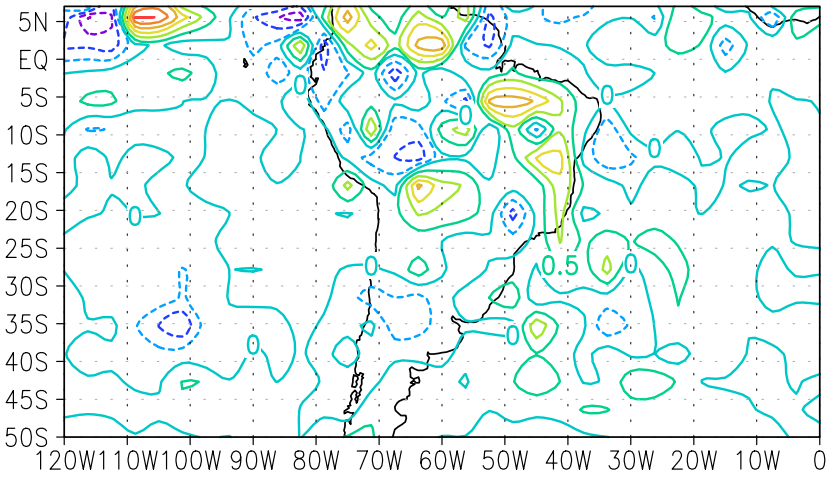
prec amp2
2nd Harmonic CTR



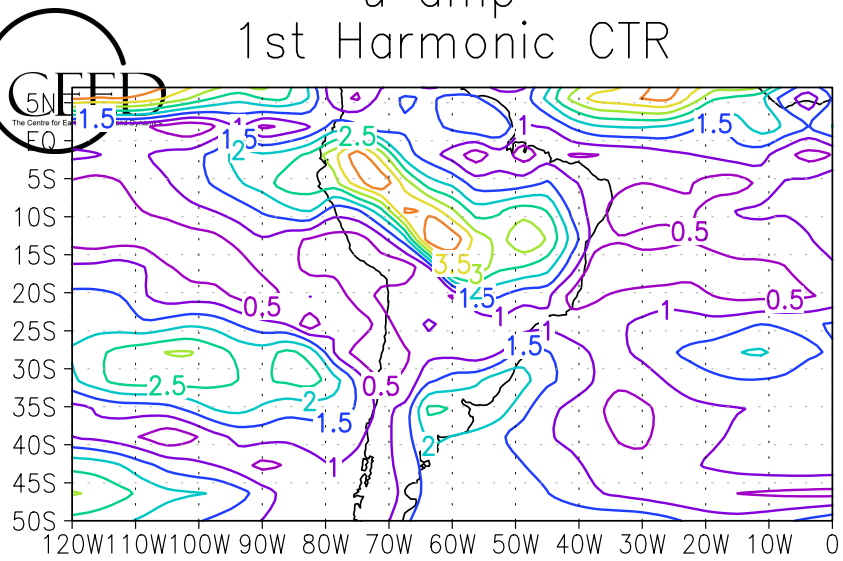
prec amp
1st Harmonic 1080ka – CTR

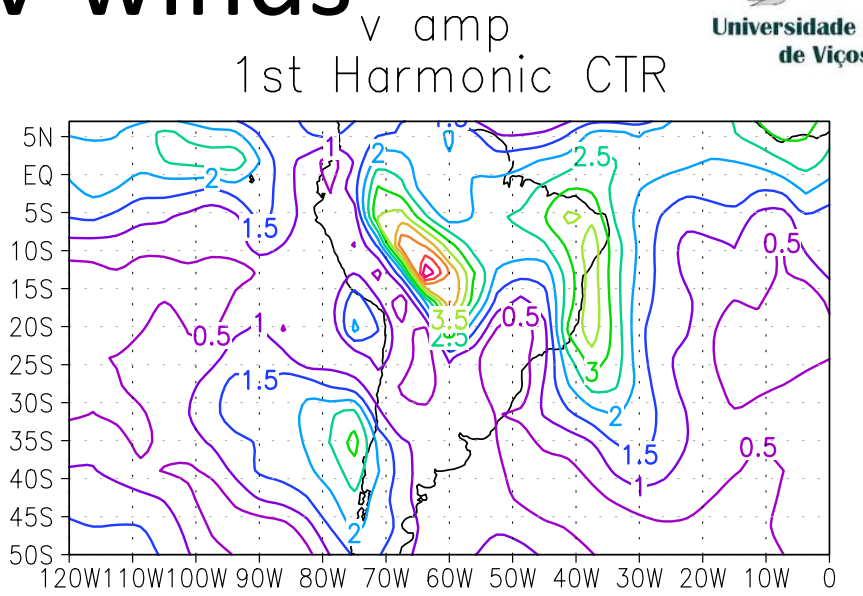


prec amp2
2nd Harmonic 1080ka – CTR



U and V winds


u amp
1st Harmonic CTR
5N
EQ
5S
10S
15S
20S
25S
30S
35S
40S
45S
50S
120W 110W 100W 90W 80W 70W 60W 50W 40W 30W 20W 10W 0


v amp
1st Harmonic CTR
5N
EQ
5S
10S
15S
20S
25S
30S
35S
40S
45S
50S
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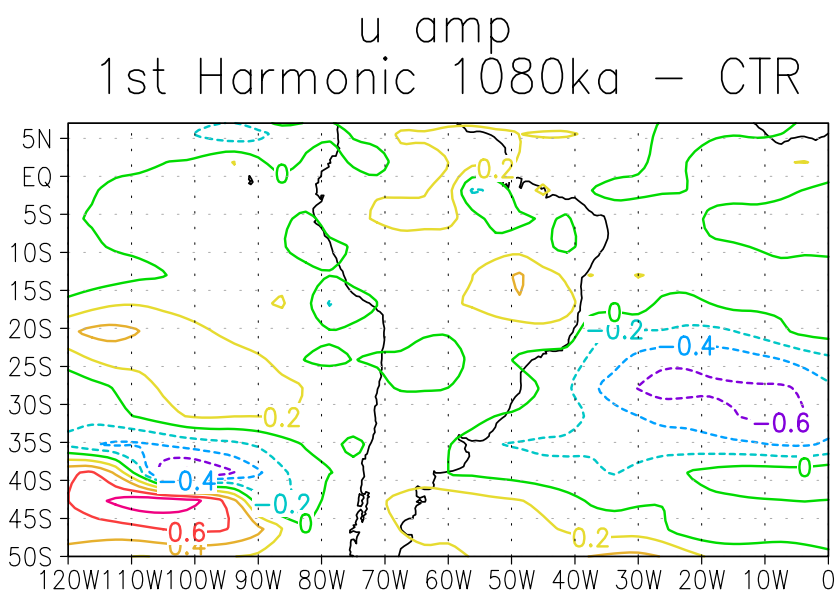
u amp
1st Harmonic 1080ka – CTR
5N
EQ
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10S
15S
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25S
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35S
40S
45S
50S
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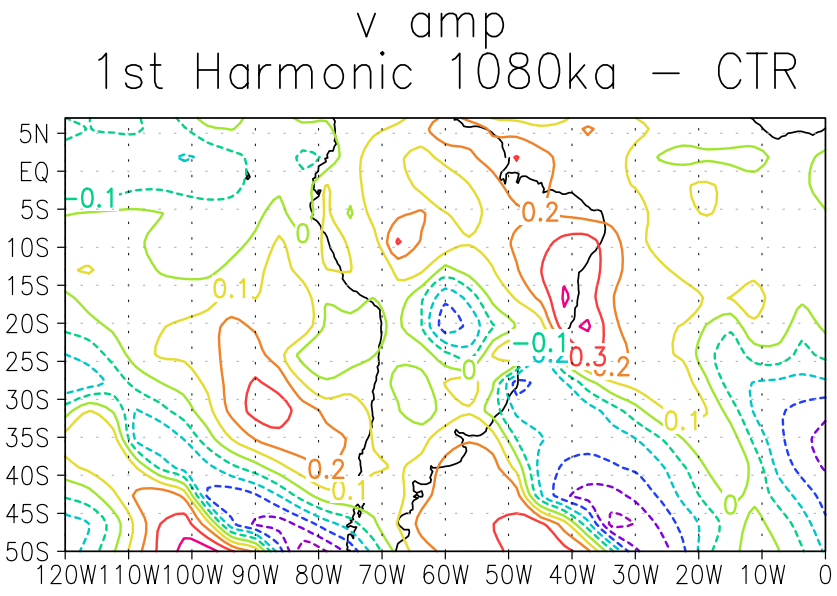
v amp
1st Harmonic 1080ka – CTR
5N
EQ
5S
10S
15S
20S
25S
30S
35S
40S
45S
50S
120W 110W 100W 90W 80W 70W 60W 50W 40W 30W 20W 10W 0

Concluding Remarks

- Speedo does a good job in simulating the main SAM patterns and correlations
- The SAM is extremely robust in respect to changes in the extra-tropics
- Future changes of SH seaice/polar SSTs may not affect the SAM substantially

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Thank you!

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